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	Richard Nussbaum	Missouri Department of Natural Resources-Hazardous Waste Program (2 copies)
	Mike Dandurand	United States Environmental Protection Agency Region VII-Air and Waste Management Division (2 copies)
FROM:	Brian Wight	URS Corporation 12120 Shamrock Plaza, Suite 100 Omaha, Nebraska 68154

CC:

ENCLOSURES

Item No.	Description
1	Final Ozone Pilot Study Report

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REMARKS

RCRA

527910

F I N A L

OZONE PILOT STUDY REPORT

FORMER AMERICAN CYANAMID FACILITY HANNIBAL, MISSOURI

Prepared for
Pfizer
Peapack, New Jersey

12120 Shamrock Plaza, Suite 100
Omaha, Nebraska 68154

Project No. 16170731

December 2013

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List of Acronyms and Abbreviations

1,2-DCA	1,2-dichloroethane
ACC	American Cyanamid Chemical
bgs	below ground surface
cfu/mL	colony forming units per milliliter
CMS	Corrective Measures Study
COC	chemicals of concern
GAC	granular activated carbon
GC	gas chromatograph
gpm	gallons per minute
HSWA	Hazardous and Solid Waste Amendments
IGTS	interim groundwater treatment system
MCB	monochlorobenzene
MDNR	Missouri Department of Natural Resources
mg/kg	milligrams per kilograms
ND	non detect
NPDES	National Pollutant Discharge Elimination System
OVA	organic vapor analyzer
PPM	parts per million
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
µg/L	micrograms per liter
URS	URS Corporation
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

This Ozone Pilot Study Report has been prepared by URS Corporation (URS) on behalf of Pfizer to document the results of using ozone to optimize the interim groundwater treatment system (IGTS) for the on-going groundwater remediation at the Former American Cyanamid Chemical (ACC) Facility, Marion County, Missouri. The former ACC site is located at 3150 Highway JJ, approximately 5 miles east-northeast of Palmyra, Missouri (**Figure 1-1**).

1.1 PURPOSE AND SCOPE

The purpose of the pilot study is to determine if ozone can prevent/reduce biofouling and plugging of the IGTS air strippers due to the presence of iron oxidizing bacteria in the extracted groundwater. The IGTS is routinely shut down due to fouling of the air stripper trays and subsequently power-washed/manually cleaned (previously acid flushed) to remove the fouling. The fouled stripper trays reduce the ability of the IGTS to effectively treat volatile organic compounds (VOCs) in the groundwater to permitted discharge levels. The destruction of the iron oxidizing bacteria would result in an increased efficiency of the IGTS, by allowing increased flow rate through the system. This pilot study report evaluates the use of ozone to prevent fouling of the air strippers and includes recommendations whether continued use of ozone is warranted.

URS prepared a Quality Assurance Project Plan and Work Plan (URS 2013) to describe the planned activities for implementation of the ozone pilot study. The proposal was submitted to the United States Environmental Protection Agency (USEPA) and the Missouri Department of Natural Resources (MDNR) for approval. The USEPA and MDNR approved the pilot study proposal in January 2013. The planned scope of work included:

- Installation of an ozone generator and assembly of the ozone distribution system
- Injection of ozone into the influent header pipe, upstream of the air stripping towers, with a 90 gallons per minute (gpm) flow rate through the system
- Performance monitoring
- Injection of ozone into the influent header pipe, upstream of the air stripping towers, with a 150 gpm flow rate through the system (not completed due to unplanned shutdowns)
- Preparation of a report summarizing the field activities and performance monitoring, with recommendations for further action

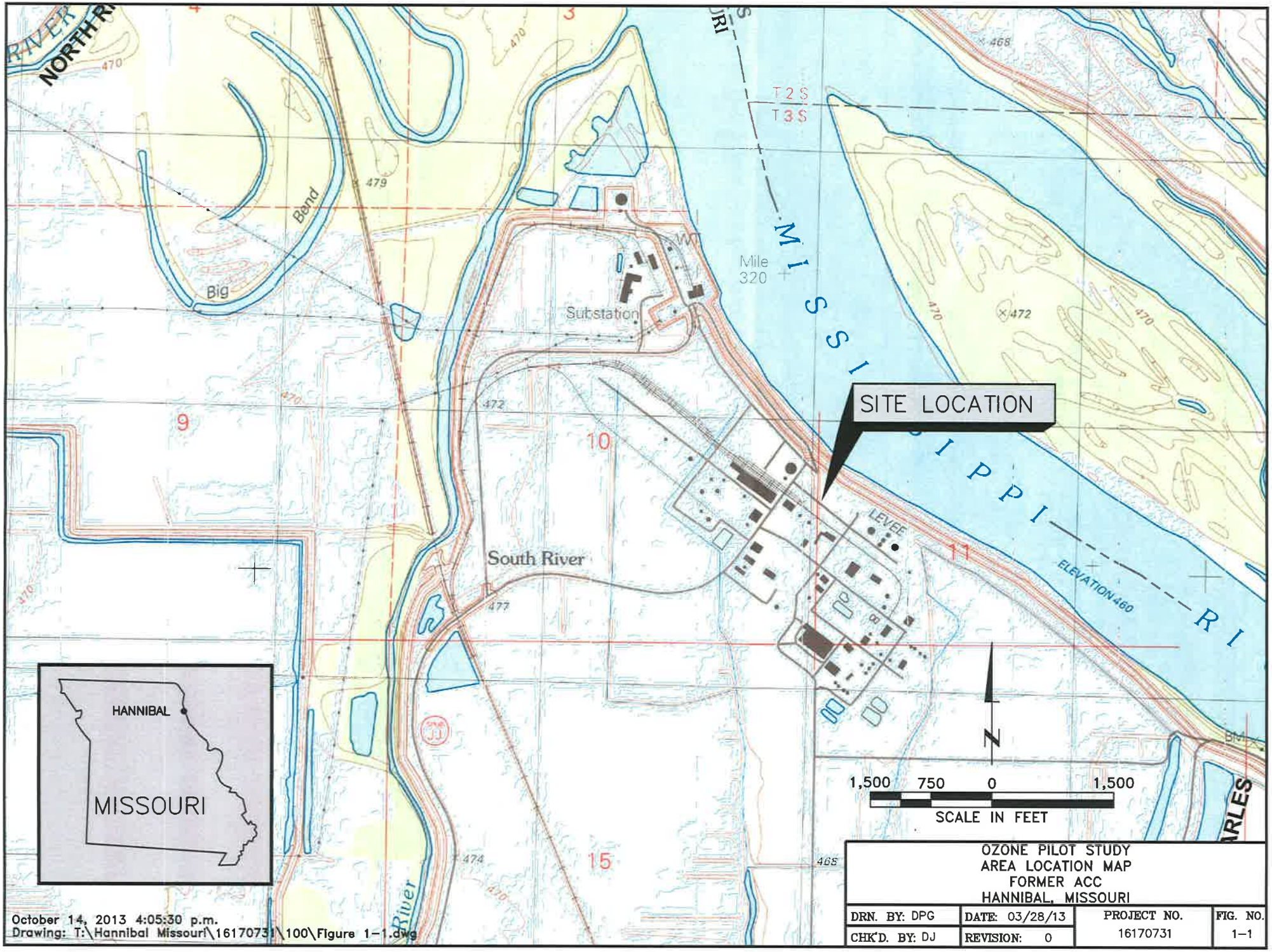
All performance monitoring groundwater samples collected were submitted to an off-site laboratory for analysis of aerobic culturable heterotrophs and total iron.

1.2 PILOT STUDY REPORT ORGANIZATION

The remainder of this report is organized into the following sections:

- **Section 2** presents background information for the project.
- **Section 3** presents the implementation of the ozone pilot study.
- **Section 4** presents the performance monitoring results.

- **Section 5** presents the conclusions and recommendations of the pilot study.
- **Section 6** presents the list of references used in this report.



OZONE PILOT STUDY
AREA LOCATION MAP
FORMER ACC
HANNIBAL, MISSOURI

DRN. BY: DPG	DATE: 03/28/13	PROJECT NO.	FIG. NO.
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This section presents a brief discussion of the regulatory and remediation history of the Former ACC Facility and a general description of the proposed ozone technology.

2.1 SITE HISTORY

The IGTS at the facility is operated pursuant to the Hazardous Waste Management Facility Permit (Permit # MOD0226075) issued by the MDNR and the Hazardous and Solid Waste Amendments (HSWA) Permit issued by the USEPA on April 25, 1990, to the former ACC. The EPA is currently the lead agency for the groundwater remediation.

The IGTS consists of three groundwater extraction wells, underground piping, and a treatment building. The extracted groundwater is metered at the treatment building, and a dose of sequesterant/chelating chemical is automatically mixed with the raw influent to minimize iron, calcium, and manganese from dropping out of solution in the form of scale. The water then passes through two inline air strippers. Hourly monitoring of VOCs in treated groundwater is completed using an in-line gas chromatograph (GC) organic vapor analyzer (OVA). Vapor from the air strippers vent through mist eliminators to the atmosphere. Operation of the IGTS began in July 2010.

The system was shut down in August 2010 due to a violation of the National Pollutant Discharge Elimination System (NPDES) discharge limits for 1,2- DCA and chlorobenzene. The system was restarted in March 2011 after installing two, 5,000 pound, granular activated carbon (GAC) vessels and the OVA. Fouling and backpressure were observed within the GAC vessels and associated bag filters after 20 days of operation. The system was again shutdown and a root cause analysis revealed an increase in iron concentration was causing a severe iron fouling of the IGTS. The sequesterant dosage and air stripper piping system was modified in July and August 2011. Backpressure and fouling continued in the GAC vessels and further evaluation was completed. The GAC systems were eventually taken off-line and the air strippers were placed in series in early October 2011. In addition, the sequesterant dosage was again modified.

Approximately every 6 weeks, the IGTS is shut down due to fouling of the air stripper trays. The fouled stripper trays reduce the ability of the IGTS to effectively remove VOCs from the groundwater to permitted discharge levels. The trays are cleaned by circulating an acid mixture through the air strippers for approximately 12 to 24 hours. Once the air stripper trays are clean, the acid mixture is neutralized, diluted with clean water, and discharged to the borrow ditch. The use of acid to clean the trays was discontinued in December 2012. The trays are now manually cleaned using a power washer and scrub brushes. The removed material is containerized in drums and disposed of per State of Missouri regulations.

During a routine NPDES site inspection in late January 2012, reddish particulates were observed in the storm drainage ditch, downstream of the NPDES outfall (outfall 001). The IGTS was shutdown in late January 2012 pending an evaluation of the particulates and the MDNR was notified. In an email dated March 28, 2012, the MDNR stated that the ditch was not considered "waters of the state" and the IGTS was restarted in late March 2012 and has run continuously since the restart, with the exception of short term (3 days or less) shut downs for acid flushing of the air strippers, and equipment repairs and maintenance.

An evaluation of iron particulate analysis and a summary of iron treatment and discharge alternatives for the IGTS were completed in January and February 2012. The results indicated a total iron concentration varying from 27,000 milligrams per kilograms (mg/kg) 400 feet downstream of Outfall 001 to 120,000 mg/kg 100 feet downstream of Outfall 001. A bacterial analysis of the water (including a sample of the GAC sludge) indicated a plate count of >1,500 colonies/ml. The water also tested positive for Fe/Mn oxidizing bacteria, including the presence of *Bacillus cereus/thuringiensis* and Gallionella. *Bacillus cereus/thuringiensis* produce a biofilm in order to capture nutrients and Gallionella uses the naturally occurring iron in the groundwater as an energy source, and secretes a "slime".

As a temporary measure to address the iron particulate discharge, two sand bag check dams were installed downstream of the outfall in June 2012 as a 6-month trial test to determine the effectiveness of sediment traps to capture the iron particulates and prevent movement of iron particulate further downstream to the borrow ditch, which is considered waters of the state. The check dams were inspected monthly and there was some particulate laden sediment observed. Due to a spring flooding event and runoff from an adjacent agricultural field, the exact nature of the sediment is difficult to discern. The sediment was removed and the ditch cleaned out by ARCADIS in November 2013. The sand bag check dams are still in place.

2.2 GEOLOGY AND HYDROGEOLOGY

The geology at the Facility is characterized by alluvial deposits as a result of current and historical flow patterns of the Mississippi River. The deposits consist of silts, clays, sands, and gravels deposited in generally fining upward sequences. A deeper fine-grained, clay unit was observed above the bedrock. The clay unit contains coarse sand, gravel, and cobbles indicative of a glacial till. Depth to bedrock in the vicinity ranges from 125 to 145 feet below ground surface (bgs). Bedrock underlying the alluvial and glacial deposits consists of shale (ARCADIS 2009).

Groundwater is encountered at the facility at a depth varying from 1 to 13 feet bgs. Groundwater velocities vary from 0.013 feet/day to 1.36 feet/day. The varying groundwater velocities are dependent on the geologic materials encountered at the shallowest groundwater depth through bedrock at 125 to 145 feet bgs. The highest groundwater velocities were calculated in the coarse sand and gravel formation encountered at approximately 35 to 45 feet bgs (ARCADIS 2009).

2.3 TECHNOLOGY DESCRIPTION

Ozone has been used as an oxidant in the water and waste water industries for decades. Iron and manganese removal along with the destruction of bacteria, virus, and odors, are one of the more common uses for ozone in drinking water systems. For treatment of bacteria and virus, the ozone kills bacteria and virus by destroying the cell wall, leaving the bacteria and virus unable to survive. The use of ozone as a pretreatment of the influent groundwater is the process used for this pilot test.

The pilot study fieldwork followed the approved Quality Assurance Project Plan and Work Plan (URS 2013) and was completed as described in this section.

3.1 PILOT STUDY SITE

The IGTS building is located on the west side of the manufacturing plant, with two of the three extractions wells located within the manufacturing plant boundaries. A site plan is shown on **Figure 3-1**. Surface features at the facility include the exterior walls of the various manufacturing buildings, parking lots, electrical transformers, screening fence, and rock drives. Topography at the IGTS building location and the manufacturing plant is flat. The IGTS is accessed from the north.

3.2 PRE-OZONE INJECTION SAMPLING

Untreated influent and treated effluent were sampled prior to the start-up of the ozone injection system. The sample analysis included aerobic culturable heterotroph and total iron. The pre-ozone injection samples were collected from a sampling port located on the combined influent line prior to the lead air stripper, and on the effluent line after the second air stripper. The results are discussed in **Section 4** and presented in **Table 4-1** and **Table 4-2**.

3.3 OZONE GENERATOR INSTALLATION AND STARTUP

Ozone generator installation activities were completed on March 11, 2013 through March 14, 2013 and the ozone generator was started on March 21, 2013. The installation activities included the installation of the ozone generator, air stripper/tray cleaning, and installation of ozone leak detection and system shutdown devices.

The ozone generator was supplied and installed by Ozone Solutions, Hull, Iowa. Ozone Solutions installed the TS-40 Ozone Gas Generator for the production of ozone for the pilot study. The ozone generator was set to produce 2.11 pounds per day of ozone at a 6 percent concentration by weight. **Appendix A** contains the specifications on the ozone generator. The ozone was directed to the combined influent pipe prior to the lead air stripper, on the downstream side of the bag filter, via ozone rated Teflon tubing. The ozone is injected into the influent stream utilizing a diffuser. The ozone generator, diffuser, and injection point are shown in photographs 2-5 of Appendix B.

The ozone generator operation is controlled by the IGTS programmable logic controller (PLC) and is turned off automatically if the wells are not operating. An ozone detector/monitor was installed at the entrance of the IGTS building so that the monitor can be viewed prior to accessing the IGTS building. The ozone generator automatically shuts down and the IGTS building exhaust fan will run, should ozone be detected at a concentration of 0.2 parts per million (ppm) within the IGTS building. An IGTS emergency shut-down switch was placed on the exterior of the IGTS building allowing the complete shut-down of the IGTS (including the ozone generator) without entering the IGTS building. The manufacturer information on the ozone safety equipment used in conjunction with the ozone generator is also provided in **Appendix A**.

Manufacturer recommendations for the use of an ozone generator were followed as noted in the Installation and Operations Manual provided in **Appendix A**.

As part of the pilot study, additional sample ports were installed at locations along the influent line prior to the lead air stripper.

Prior to beginning the injection of ozone, both air strippers were cleaned and photographed. The air stripper trays were removed, scraped, and washed to remove any buildup. The interior of the air strippers were also scraped, washed, and air stripper sumps cleared of any buildup. The removed material was containerized, sampled, and disposed of per State of Missouri regulations. The air strippers/trays were then photographed **(Appendix B).** This allowed for an accurate comparison of ozone treatment to the current use of sequestrant. Sequestrant was not used during the pilot study. The Ozone Background Study Report is attached in Appendix C.

3.4 OZONE BACKGROUND STUDY ACTIVITIES

Elevated levels of ozone (0.08 to 0.14 ppm) were observed on the ozone monitor mounted near the personnel entry door prior to start-up of the ozone generator. An ozone background study was completed at the facility to determine the source of the elevated levels of ozone observed at the monitor.

The ozone background study consisted of the collection of ozone readings outside and inside the IGTS on March 21, 2013. Ozone levels were measured in real time utilizing two handheld AeroQual Series 500 Ozone Monitors (**Appendix C**). The AeroQual Series 500 Ozone Monitors were used to measure ozone levels inside the IGTS building and within 100 feet of the building. Ozone readings from inside the IGTS building were also collected from the factory calibrated Eco-Sensor OS-4 ozone monitor mounted near the personnel door.

The following discusses the ozone background study results completed in and near the IGTS building. The Ozone Background Study report along with ozone detection maps are presented in **Appendix C**. The background study was completed on March 21, 2013. The ozone concentrations measured outside the building with the ozone generator 'OFF' and the ventilation fan 'OFF', ranged from 0.016 ppm to 0.068 ppm. The concentration range inside the building was measured at 0.028 ppm to 0.044 ppm. The recently installed Eco-Sensor OS-4 monitor measured 0.100 ppm during the same time frame and it was presumed that the factory calibration of the Eco-Sensor OS-4 may not be correct.

The ozone concentrations measured inside the building, with the ozone generator 'ON' and the ventilation fan 'OFF', ranged from 0.019 ppm to 0.064 ppm. The ozone concentrations measured inside the building, with the ozone generator 'ON' and the ventilation fan 'ON', ranged from 0.026 ppm to 0.042 ppm. The Eco-Sensor OS-4 monitor's maximum concentration measurement was 0.100 ppm during the same time frame.

Ozone was detected in the effluent air stream at a maximum concentration of 0.013 ppm. This result is likely instrument accuracy/sensitivity reading. This result indicates that ozone is not being released to the atmosphere from the air stripper ventilation stacks atop the building.

The static ozone alarm condition level (for generator shut 'OFF') was set at the OSHA time weighted average concentration of 0.10 ppm. If the 0.10 ppm alarm level routinely shuts down the generator, the alarm level can be increased to 0.15 ppm. If the alarm level is increased to 0.15 ppm, work duration in the building will be limited to a total of 5 hours and 20 minutes per day when ozone concentrations are >0.10 ppm and <0.15 ppm.

A new ozone monitor was installed in the IGTS building on April 4, 2013. The alarm condition for the unit was set at 0.10 ppm. Once ozone concentrations reach 0.10 ppm the ozone generator will shut down.

Background ozone concentrations were again obtained inside and outside the IGTS building on April 4, 2013. The concentrations ranged from 0.032 to 0.062 ppm both inside and outside of the IGTS building. The indoor monitor's maximum concentration measurement was 0.03 to 0.07 ppm during the same time frame.

The IGTS, including the ozone generator, was allowed to run in "Auto" mode beginning on April 5, 2013. The system began to "alarm" on a regular basis after approximately one week of operation. The alarm set point was subsequently increased from 0.10 ppm to 0.20 ppm on April 22, 2013.

3.5 OZONE INJECTION MONITORING ACTIVITIES

Ozone monitoring activities were completed to evaluate the effectiveness of the ozone treatment. Both analytical testing and visual observations were used to determine whether the injection of ozone into the influent is working and to what degree. Analytical testing included collection and analysis of the influent and effluent for aerobic culturable heterotrophs and total iron. The samples were collected from sampling ports located on the influent line (prior to air stripper 1the lead air stripper), between air stripper 1 and air stripper 2, and on the effluent line after the second air stripper. Visual observation of the air strippers and the effluent were monitored for increase/decrease in discoloration and/or biofouling. The influent and effluent was to be analyzed weekly for aerobic culturable heterotrophs and the analytical results compared to the baseline sample results. Due to unplanned shutdowns of the IGTS (**Section 3.6**) and the fluidity of the system, the initial weekly sampling of the influent/effluent did not occur. The results of the Ozone Injection Monitoring Activities are discussed in **Section 4.3**. The results are presented in **Table 4-1 and Table 4-2**.

3.6 UNPLANNED IGTS SHUTDOWN

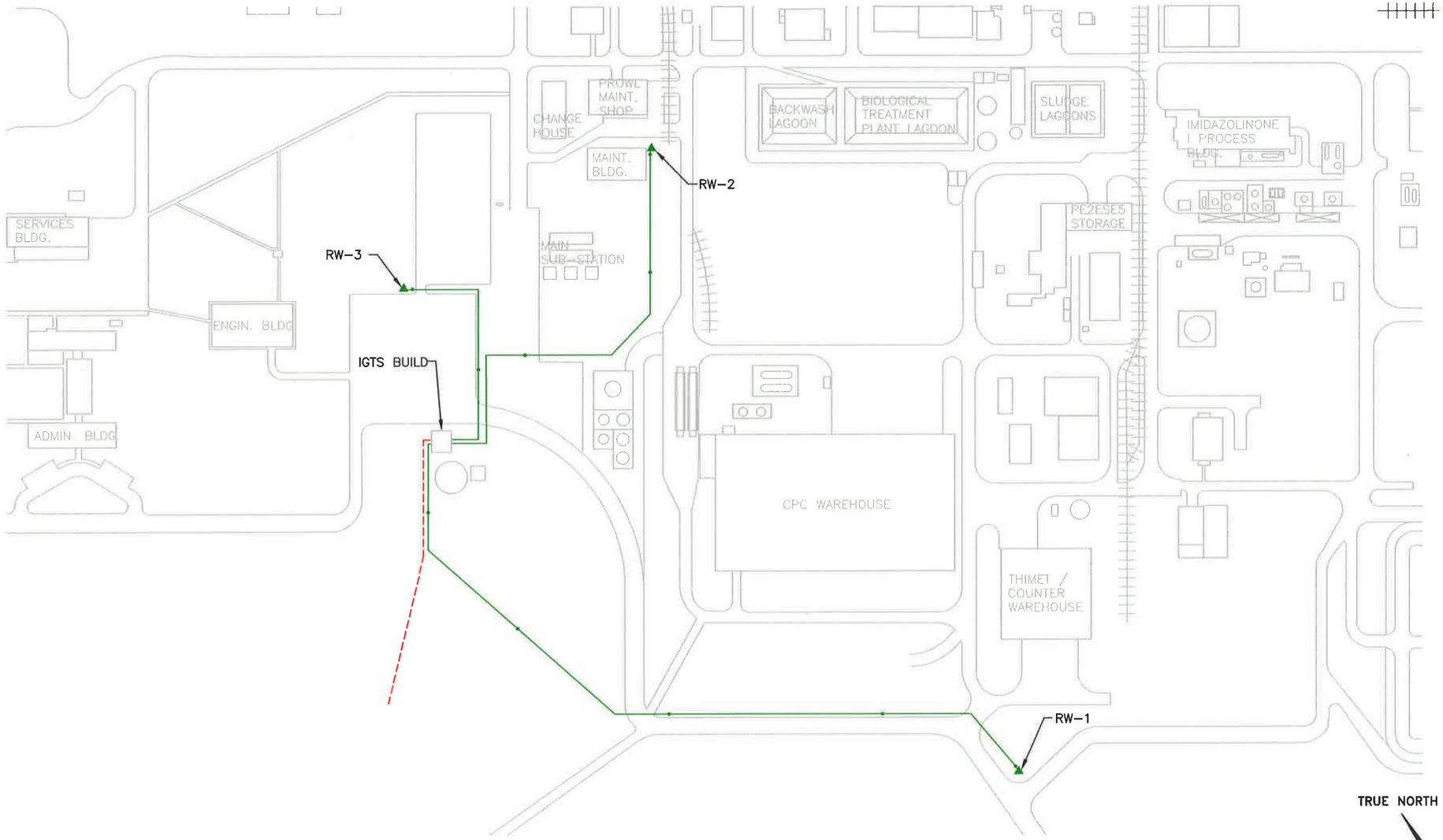
The ozone generator was started on March 13, 2013, beginning the 6-month pilot study. During the 6-month pilot study, the IGTS was shut down multiple times. The reason for the shut downs varied from environmental factors to equipment failure. The majority of the system shut downs

were short term (less than 5 days), however the system was shut down for an extended amount of time in March for an ozone background study and again in April/May as a precautionary measure associated with flooding at the site. Due to the various shutdowns and equipment failures, the maximum influent flow rate into the IGTS during the pilot study was 90 gpm. The following lists the shutdowns (shutdowns of less than 24-hours not included), and reason for shut downs, that occurred during the Pilot Study:

- March 14 through April 4, 2013 for completion of an ozone background study (IGTS remained on with ozone generator off).
- April 15 through April 17, 2013 for cleaning of air strippers/trays and pump replacement (reestablish background as a result of ozone background study).
- April 19 through May 7, 2013 as precautionary measure due to flooding at the site.
- May 13 through May 15 due to a sump failure.
- May 18 through May 23, 2013 due to a weld failure on air stripper 1.
- June 24 through June 25, 2013 to jet/flush out discharge line.

LEGEND

- ▲ GROUNDWATER EXTRACTION WELL LOCATION
- • CLEANOUT
- GROUNDWATER CONVEYANCE PIPING LOCATION
- TREATED GROUNDWATER DISCHARGE
- RAILROAD TRACKS



PLAN NORTH

TRUE NORTH

N

37°-30'

200 100 0 200

SCALE IN FEET

OZONE PILOT STUDY
SITE PLAN
FORMER ACC
HANNIBAL, MISSOURI

DRN. BY: LLS	DATE: 10/14/13	PROJECT NO.	FIG. NO.
CHK'D. BY: DJ	REVISION: 0	16170731	3-1

October 14, 2013 4:16:19 p.m.
Drawing: T:\Hannibal Missouri\16170731\100\Figure 3-1.dwg

The purpose of the performance monitoring program is to evaluate the effectiveness of the ozone treatment. Both analytical testing and visual observations were used to determine whether the injection of ozone into the influent was effective and to what degree. This section describes the pre-ozone injection (baseline) results, ozone background study results, and ozone injection results for the pilot study.

4.1 PRE-OZONE INJECTION SAMPLING RESULTS

The purpose of the baseline groundwater monitoring, completed on March 13, 2013, was to establish a baseline of the bacteria concentration in the groundwater stream. In addition, the air stripping towers/trays were cleaned to establish a visual baseline of the air stripping towers/trays. The drainage ditch was also observed for any discoloration. Groundwater samples were collected for laboratory analysis of aerobic culturable heterotrophs. The analytical results and visual observations are presented in **Table 4-1 and Appendix B** and discussed below:

- At the combined influent, the bacteria count was 6.00 E +01 colony forming units per milliliter (cfu/mL).
- Between air stripping tower 1 and air stripping tower 2, the bacteria count was 4.10 E +02 cfu/mL.
- At the effluent, the bacteria count was 7.60 E +02 cfu/mL.
- All mass build-up was removed from the air stripping towers and trays. The trays were covered with a black, hard material with a glassy appearance. The material covered the majority of the air stripper trays, including the air holes. Scrapers and a screwdriver were required to clean out the trays and clear the air holes. There was minimal staining of the air stripping towers/trays remaining after the cleaning event. There was minimal reddish brown discoloration (mass) observed in the drainage ditch.

4.2 OZONE INJECTION MONITORING RESULTS

The following discusses the ozone injection monitoring results. The ozone monitoring included both visual observations and analytical results over the 6-month pilot study period. Ozone monitoring began on March 14, 2013. Due to the unexpected shut-downs throughout the 6-month pilot study period, ozone injection monitoring, in particular the anticipated sample collection schedule, was altered to try and account for the unexpected shut-downs. The ozone injection monitoring consisted of the collection of groundwater for aerobic culturable heterotrophs and total iron. In addition, one dissolved iron sampling event was completed to determine the amount of dissolved iron in the treatment stream. The analytical results of the ozone injection monitoring presented in **Tables 4-1 and 4-2**, and discussed below:

March 14, 2013 (system was shut down after sample collection for completion of background study)

- At the combined influent, the bacteria count was 1.35 E +01 cfu/ml and the iron concentration was 18,600 micrograms per liter (ug/L).
- Before air stripping tower 1, the total iron concentration was 19,100 ug/L.
- Between air stripping tower 1 and air stripping tower 2, the bacteria count was 4.45 E +02 cfu/mL and the total iron concentration was 17,500 ug/L.
- At the effluent, the bacteria count was 1.05 E +03 cfu/mL and the total iron concentration was 17,400 ug/L.
- Visual observations indicated unrestricted air flow through the trays with minimal mass buildup on the trays. There was no reddish brown mass observed in the drainage ditch.

After completion of the ozone injection monitoring, the ozone generator was shut down after one day of operation pending the results of the Ozone Background Study.

May 23, 2013

- At the combined influent, the bacteria count was 1.35 E +01 cfu/mL.
- Prior to air stripping tower 1, the bacteria count was 2.88 E +02 cfu/mL
- Between air stripping tower 1 and air stripping tower 2, the bacteria count was 5.75 E +02 cfu/mL.
- At the effluent, the bacteria count was 4.55 E +02 cfu/mL
- Visual observations indicated minimal mass buildup on the trays with no reddish brown mass observed in the drainage ditch.

Due to an extended period of system shut-down, all mass build-up was removed from the air stripping towers and trays, with minimal staining of the air stripping towers/trays remaining. It should be noted that there was minimal mass build-up noted in the air stripping towers and on the trays.

June 13, 2013

- At the combined influent, the bacteria count was 1.15 E +01 cfu/mL.
- Prior to air stripping tower 1, the bacteria count was 3.48 E +02 cfu/mL
- Between air stripping tower 1 and air stripping tower 2, the bacteria count was 2.15 E +03 cfu/mL.
- At the effluent, the bacteria count was 3.92 E +03 cfu/mL.
- Visual observations indicated unrestricted air flow through the trays with minimal mass buildup on the trays with no reddish brown mass observed in the drainage ditch.

August 15, 2013

- Prior to the August 15, 2013 sampling event, the ozone injection point was moved upgradient of the static inline mixer to improve mixing and extend contact time. At the combined influent, the bacteria count was 5.00 E +00 cfu/mL and the total iron concentration was 13,100 ug/L {non detect (ND) for dissolved iron}.
- Prior to air stripping tower 1, the bacteria count was 9.50 E +01 cfu/mL and the total iron concentration was 10,300 ug/L (ND for dissolved iron).
- Between air stripping tower 1 and air stripping tower 2, the bacteria count was 3.45 E +02 cfu/mL and the total iron concentration was 15,000 ug/L (ND for dissolved iron).
- At the effluent, the bacteria count was 6.40 E +02 cfu/mL and the total iron concentration was 11,100 ug/L (ND for dissolved iron).
- At the effluent outfall, the bacteria count was 2.57 E +03 cfu/mL and the total iron concentration was 12,800 ug/L (ND for dissolved iron).
- Visual observations indicated unrestricted air flow through the trays with minimal mass buildup on the trays and no reddish brown mass observed in the drainage ditch.

The air stripping towers and trays were cleaned with minimal staining of the air stripping towers/trays remaining. It should be noted that there was a small amount of mass build-up observed in the air stripping towers and on the trays. The material observed on the trays appeared to be of a liquid/fluff consistency that did not plug and/or restrict air flow through the trays.

TABLE 4-1
SUMMARY OF BACTERIA DETECTED
FORMER ACC FACILITY
HANNIBAL, MISSOURI

Sample Date	Combined Influent (cfu/mL)	Before Air Stripper 1 (cfu/mL)	Between Air Stripper 1 and 2 (cfu/mL)	Effluent (cfu/mL)	Effluent Outfall (cfu/mL)
2/07/2013	4.00 E +02	NS	NS	NS	NS
3/13/2013	6.00 E +01	NS	4.10 E +02	7.60 E +02	NS
3/14/2013	1.35 E +01	NS	4.45 E +02	1.05 E +03	NS
5/23/2013	1.35 E +01	2.88 E +02	5.75 E +02	4.55 E +02	NS
6/13/2013	1.15 E +01	3.48 E +02	2.15 E +03	3.92 E +03	NS
8/15/2013	5.00 E +00	9.50 E +01	3.45 E +02	6.40 E +02	2.57 E +03

Abbreviations:

cfu = colony forming units

mL = milliliter

NS = not sampled

combined influent = sample location before ozone diffuser

before air stripper 1 = sample location after ozone diffuser, prior to air stripper 1 influent

TABLE 4-2
SUMMARY OF TOTAL IRON DETECTED
FORMER ACC FACILITY
HANNIBAL, MISSOURI

Sample Date	Combined Influent (ug/L)	Before Air Stripper 1 (ug/L)	Between Air Stripper 1 and 2 (ug/L)	Effluent (ug/L)	Effluent Outfall (ug/L)
3/14/2013	18,600	19,100	17,500	17,400	NS
4/16/2013	NS	17,200	NS	NS	NS
8/15/2013	13,100	10,300	15,000	11,100	12,800
8/15/2013*	ND	ND	ND	ND	ND

Abbreviations:

cfu = colony forming units

mL = milliliter

ND = non detect

NS = not sampled

combined influent = sample location before ozone diffuser

before air stripper 1 = sample location after ozone diffuser, prior to air stripper 1 influent

* = dissolved iron result

The ozone pilot study was completed to determine if ozone can prevent biofouling and plugging of the IGTS air strippers due to the presence of iron oxidizing bacteria in the extracted groundwater. The following describes the conclusions and recommendations as a result of the Ozone Pilot Study.

5.1 CONCLUSIONS

The ozone generator supplied and installed by Ozone Solutions was the TS-40 Ozone Gas Generator. The ozone generator was producing 2.11 pounds per day of ozone at a 6 percent concentration by weight. The ozone was directed to the influent pipe via ozone rated Teflon tubing and injected into the influent stream utilizing a diffuser. The ozone generator operation is controlled by the IGTS PLC and is turned off automatically if the wells are not operating. An ozone monitor was installed at the entrance of the IGTS building (visible from outside the building). The ozone generator automatically shuts down and the IGTS building exhaust fan runs, should ozone be detected at a concentration of 0.10 ppm within the IGTS building. An IGTS emergency shut-down switch was placed on the exterior of the IGTS building. The emergency shut-down allows the complete shut-down of the IGTS (including the ozone generator) without entering the IGTS building.

Prior to and upon startup of the ozone injection system, elevated levels of ozone (0.08 to 0.14 ppm) were observed on the ozone monitor. An ozone background study was completed at the facility and confirmed the source of the elevated levels of ozone observed within the building was the result of background levels of ozone. In addition, a new ozone monitor (Ozone Solutions Ozone Controller Model ES-600) was installed in the IGTS building. The alarm condition for the unit was set initially set at 0.10 ppm. The system began to "alarm" on a regular basis after approximately one week of operation and the alarm set point was increased from 0.10 ppm to 0.20 ppm. The new alarm set point has reduced the amount of alarm conditions observed at the IGTS.

During the pilot study there were multiple unplanned shutdowns of the IGTS. The reason for the shutdowns varied from equipment failure to acts of nature. The majority of the shut downs were less than 5 days. However, the Ozone Background Study resulted in the ozone injection system being shut down for 22 days and flooding at the facility resulted in the IGTS (including the ozone injection system) being shut down for 19 days. Due to the various shutdowns and system capabilities, the maximum influent flow rate during the pilot study was 90 gpm. In addition the air strippers/trays were cleaned after the extended, unplanned shutdowns. The amount of buildup observed during the cleaning events was minimal. The material observed was generally a reddish brown colored material that was a liquid/fluff consistency. The air holes in the trays were not plugged and air flow through the trays was minimally restricted.

The bacteria analytical results indicated an increasing amount of bacteria through the IGTS during the background sampling. The background sample results increased from 6.00 E +01 at the influent to 7.60 E +02 at the effluent. The ozone injection results also increased through the IGTS. The ozone injection results varied from 5.00 E +00 to 1.35 E +01 at the influent and 4.55 E +02 to 3.92 +03 at the effluent. The use of ozone is intended to control the bacteria and not eliminate it.

The iron samples were collected to determine if ozone is oxidizing the iron in the influent stream. The results of the sampling indicated there is iron in the influent. The influent results varied from 13,100 ug/L to 18,600 ug/L. The effluent iron concentrations varied from 11,100 ug/L to 17,400 ug/L. There is a slight decrease in the iron concentration from the influent to the effluent indicating there is minimal oxidation of the iron due to the ozone. The air strippers, trays, and IGTS outfall were inspected for the presence of oxidized iron. Oxidized iron was not observed in the air strippers or the air stripper trays. There was also no reddish orange mass observed at the drainage ditch associated with the outfall.

Planned and unplanned cleaning events were completed throughout the pilot study. The cleaning events consisted of removal and power washing of the trays. The time between cleaning events varied from 4 to 7 weeks. In general, the mass buildup in the tray was a reddish brown, soft, material that had a liquid/fluff consistency. The material did not significantly plug and/or restrict air flow through the trays. Prior to the use of ozone, the material was a black, hard material with a glassy appearance that significantly reduced air flow through the trays. With the continued use of ozone, less frequent cleaning of the air stripper trays is anticipated.

5.2 RECOMMENDATIONS

The following recommendations are made based on the results of the pilot study:

- Continue treatment of the influent stream using ozone.
- Increase the ozone contact time with the influent stream by moving the ozone diffuser further up-stream of air stripper 1, the lead air stripper (completed in September 2013).
- Install a pump/venturi side stream system to increase the concentration of ozone present in the influent stream.
- If the flow rate is increased to 150 gpm, the air stripping towers/trays will need to be monitored for buildup. If the rate of buildup significantly increases, consider utilizing the acid circulation tank as an ozone pretreatment tank. The use of the acid tank would increase the ozone contact time with the influent stream providing better bacteria control. Installation of additional equipment may be necessary (pump, piping, wiring, alarm systems, etc.).

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ARCADIS. 2009. Additional Groundwater Delineation and Capture Zone Modeling Documentation Report. Former American Cyanamid Company. February.

ARCADIS. 2006. Phase II RCRA Facility Investigation. Former American Cyanamid Company.

ARCADIS. 2005. RCRA Facility Investigation Report. Former American Cyanamid Company. July.

URS 2013. Quality Assurance Project Plan and Work Plan. Former American Cyanamid Company. January.

URS 2012. Health and Safety Plan. Former American Cyanamid Company. November.

451 Black Forest Road Hull, IA 51239 Ph: (712) 439-6880 Fax: (712) 439-6733

TS-40

40 g/hr Turnkey Ozone Generation System

Installation and Operation Manual

Cautions, Warnings and Hazards

Ozone is a powerful oxidizing agent. Observe strict operating procedures when using ozone equipment. Ensure that the TS-40 is in a well-ventilated area.

Note: If the operator has asthma, he/she must not enter an ozonated airspace. Ozone can induce an asthma attack.

WARNING Ozone is an extremely aggressive and powerful oxidizer. The Occupational Safety and Health Administration (OSHA) 8-hour exposure limit is 0.10-PPM. The OSHA 15-minute exposure limit for ozone is 0.3 PPM. Above 0.3 PPM, there is the risk of damage to respiratory tissues.

WARNING People who have no sense of smell should not operate this equipment.

WARNING **Never attempt to verify ozone production by directly breathing or smelling the ozone outlet or an ozone-tubing outlet.**

WARNING The system uses ozone compatible Stainless and Teflon tubing. The Ozone Generators under high pressure poses the possibility of ozone leaks to occur. In the event of an ozone leak, immediately shut down the system.

WARNING Use only Teflon or other approved methods for ozone tubing. Ensure tubing connections between the Ozone System and the point of use are secure and in good condition. Failure to do so could result in the discharge of dangerous amounts of ozone into an occupied space.

The TS- 40 contains an OXYGEN CONCENTRATOR (a.k.a. Oxygen Generator) for the production of high concentration oxygen to supply the Ozone Generator.

Although oxygen itself is not combustible, it can be very dangerous. It greatly accelerates the burning of combustible materials.

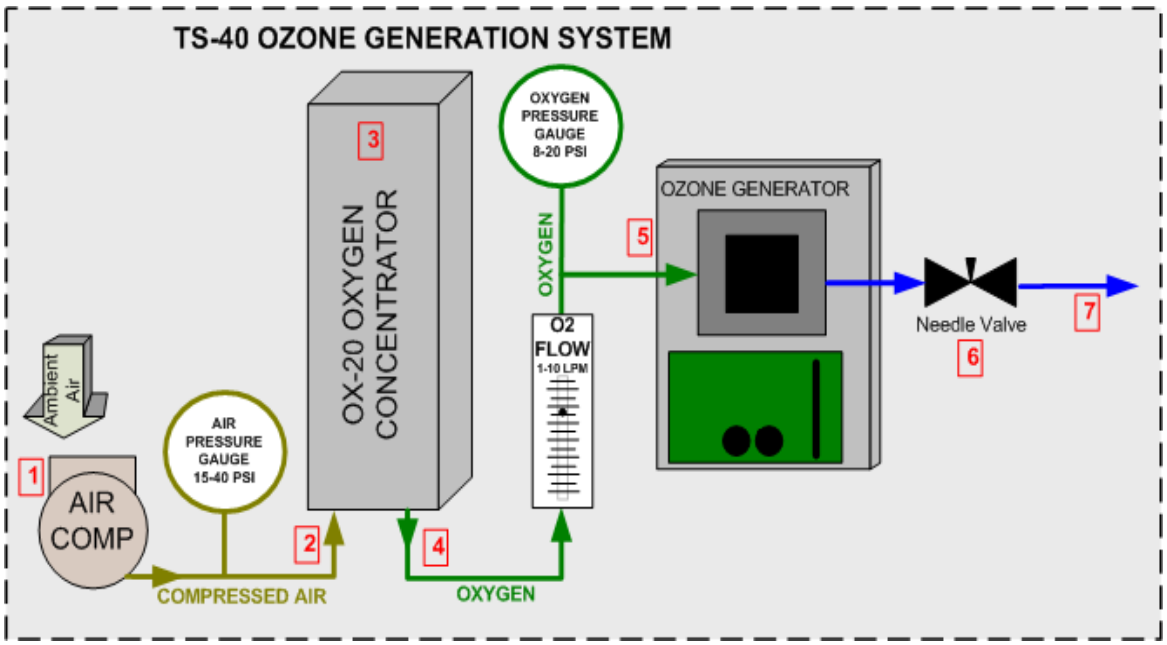
- Precautions should be taken to avoid a fire in the area of the generator.
- Smoking should not be permitted in the area where the generator is located.
- All oxygen connections and hoses should be kept clean and free of grease, oil and other combustible materials.
- Valves controlling oxygen flow should be opened and closed slowly to avoid the possibility of fires or explosions that can result from adiabatic compression.
- When bleeding a tank or line, stand clear and do not allow oxygen to embed itself within clothing. A spark could ignite the clothing violently.
- High-pressure gases may be present within the system. Valves should be opened and closed slowly. Safety glasses and hearing protection should be worn at all times while gases are being vented.
- Do not attempt to modify or enhance the performance of the Generator in any way.

Table Of Contents

Introduction

The TS-40 Ozone Generator is a complete air preparation and ozone generation system. The unit includes an integrated Air Compressor, Oxygen Concentrator, and Ozone Generator. No external air supply is required is not required. Contained within the TS-40 chassis is a TG-40 Ozone Generator, capable of producing 40 gm/hr of ozone at 6% concentration by weight. Using pressurized oxygen from the Oxygen Concentrator, the Ozone Generator will achieve from 2 to 40 gm/hr of ozone production at flows of 1-10 LPM and at pressures of 10-20 PSI.

System Flow Diagram and Theory of Operation



1. Air Compressor takes in ambient air & delivers it to the Oxygen Concentrator.
2. Compressed air enters Oxygen Concentrator.
3. Oxygen Concentrator removes nitrogen from the air using pressure swing absorption, leaving 90-95% oxygen. Effluent nitrogen is vented to atmosphere.
4. 90-95% Oxygen leaves the Oxygen Concentrator at a rate of up to 10 LPM under 8-20 PSI pressure. Pressure & flow are regulated by an internal needle valve downstream of the Ozone Generator, see #6 below.
5. Oxygen enters Ozone Generator where it is utilized to produce high concentration ozone under pressure.
6. Panel mounted Needle Valve will allow adjustment of oxygen flow from the TS-40 Ozone Generator. Oxygen flow must never exceed 10 LPM of flow.
7. Ozone exits TS-40 via the OZONE OUT port.

Ozone Generator Performance

The Ozone Generator is designed to produce ozone from oxygen under pressure. While maximum ozone production (by volume) will be achieved at higher pressures and flows, the Oxygen Concentrator is limited to a given pressure (8-20 PSI) at a given flow (1-10 LPM).

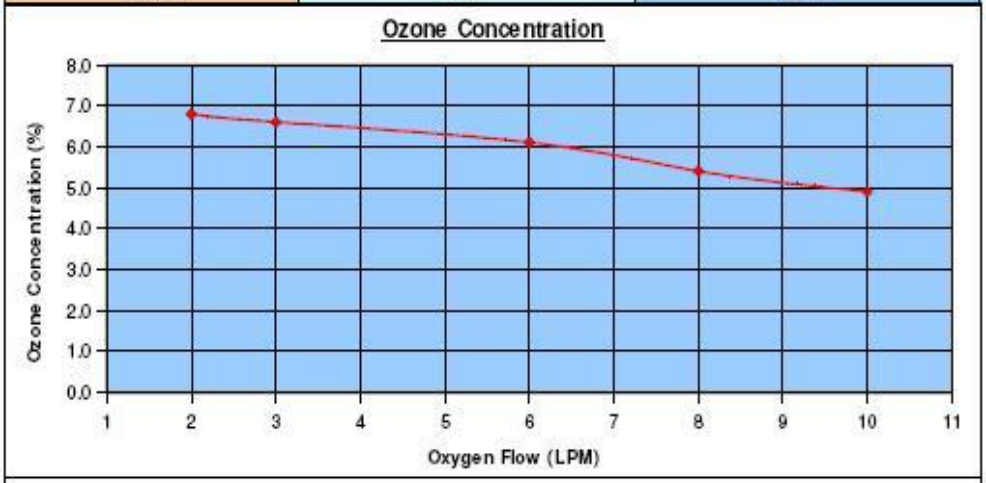
"Optimum" ozone production is dependent on the application. Some applications require higher concentration ozone at a lower flow rate (lower overall production by volume), while others may require maximum overall production by volume (lower concentration). Desired ozone flow can be determined by the user according to the chart on the following page.

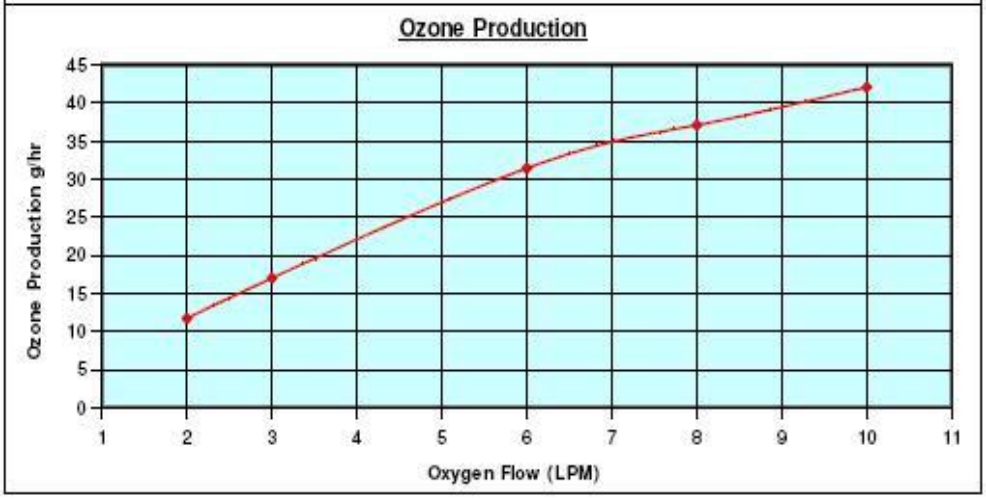
Ozone Generator Performance Chart

TS-40 Ozone Generator Performance

TS-40 Ozone System

Oxygen Flow in LPM	Ozone Concentration, % by weight	Ozone Production in g/hr
2.00	6.80	11.67
3.00	6.60	16.99
6.00	6.10	31.40
8.00	5.40	37.07
10.00	4.90	42.04





All tests were performed at 70-deg F
Ozone Generator was run at each flow rate for 1 hour prior to recording reading

Installation

VENTILATION

The TS-40 should be installed in a clean dry area. The area must be free of dust, oil, acid or other volatile vapors or V.O.C.'s (volatile organic compounds).

The TS-40 is an air-cooled system. Operating environment will affect overall ozone output, as higher temperatures will limit the capabilities of the Ozone Generator. As a general rule: *the highest the ozone output is achieved in a lower-temperature environment (80°F or less).*

Ambient temperature may not exceed 95°F or 85% Relative Humidity, at conditions beyond this the ozone output & longevity of the system will be significantly affected. If necessary, air conditioning and/or adequate ventilation should be utilized in the room in order to achieve maximum efficiency and longevity.

> **IMPORTANT:** If the relative humidity could exceed 85%, a dehumidifier must be installed near the TS-40 to maintain optimum conditions. Any high quality dehumidifier may be obtained from your local Home Depot, Lowe's Home Improvement, or other supplier.

Without adequate ventilation in a confined space, oxygen levels may be reduced such that the Oxygen Concentrator will not operate efficiently. If oxygen levels are reduced the longevity of the Zeolite absorption material in the Oxygen Concentrator could be compromised resulting in reduced ozone output and possible damage to the Ozone Generator. In addition, inadequate ventilation will result in heat buildup & eventual overheating of the system.

> **In order to prevent oxygen reduction, or ozone buildup in a confined space (less than 2000 cubic feet):** There should be at least 3 air changes per hour in the space whenever the TS-40 is installed in a space *smaller than 2000 cubic feet*.
>
> **In order to prevent excessive heat:** Air conditioning or suitable ventilation should be used as required to maintain temperature not to exceed 95° F or humidity not to exceed 85% RH.

Optionally, it is also possible to vent the effluent from the Oxygen Concentrator outside a confined space and thereby prevent oxygen reduction in the space.

For assistance with venting the Oxygen Concentrator or if the room conditions are in question, contact Ozone Solutions at 712-439-6880 for assistance.

LOCATION & MOUNTING

Location

- **Weather:** Choose a location for the TS-40 that does not allow rain or condensation to contact the unit. *The TS-40 is not weather proof*. It must be operated indoors or under a roof in a non-condensing environment.
- **Mobile Units:** If the system is to be mounted in a mobile unit (such as a trailer or movable building), mechanical shock and vibration prevention measures should to be taken to protect the TS-40 from damage during relocation of the mobile unit. Never subject the unit to any kind mechanical shock or vibration (including shipping) unless it is standing upright, or unless adequate measures have been taken to secure the Air Compressor (mounted inside the TS-40).

Positioning & Accessibility

- The TS-40 should be positioned in such a way that the front door can be fully opened for future maintenance.
- All controls and connections are located on the right-hand side of the enclosure; these must be fully accessible for operation.
- Located on the left-hand side and front door are a total of four (4) filtered air inlets. These must have a minimum 6 inch space free of obstruction for air movement, and must remain accessible for future maintenance.

Mounting

- **Wall Mounting:** The mounting tabs located on the top of the TS-40 are NOT intended to support the weight of the TS-40. A heavy-duty shelf or other means of support must be used to set the unit on, and then the mounting tabs on top may be used to secure the TS-40 to prevent tip-over or other movement. If necessary the leveling feet can be removed & the TS-40 may be secured at the bottom.
- **Floor Mounting:** The TS-40 may be set directly on the floor. In situations where there is no risk of danger from tip-over or movement due to vibration, the TS-40 may remain unsecured. If necessary the mounting tabs on top may be used to secure the TS-40 to prevent tip-over or other movement. Also the leveling feet can be removed & the TS-40 may be secured at the bottom.

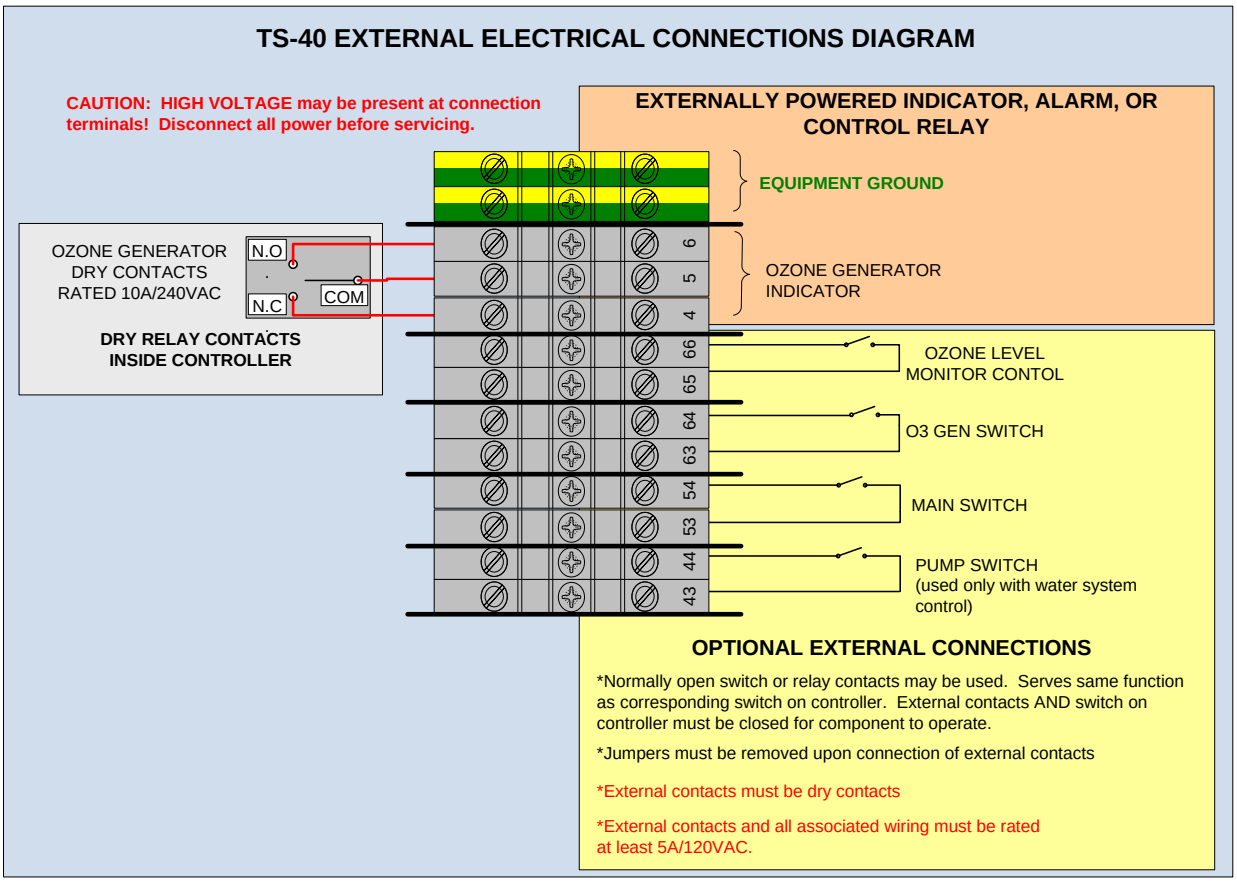
CONNECTIONS

Electrical Power

The TS-40 is equipped with a power cord and can be plugged into a dedicated 120V/15A receptacle. In some locations, 20 Amp overcurrent protection may be required to allow for compressor startup.

Optional Electrical Control Connections

The TS-40 is equipped with terminals to allow connection of external switching; or external alarms or equipment. The TS-40 electrical control circuitry is located inside the enclosure in the upper right-hand corner. Drill holes as necessary for connection of electrical wiring. The terminals are labeled as follows:



Ozone Out Connection

The OZONE OUT connection fitting is located on the right-hand side of the TS-40, just below the pressure gauges. It is a standard ¼ inch O.D. Stainless-Steel Compression fitting.

Connect any Ozone Resistant tubing with rigid walls for use in a compression fitting. Ensure that the compression fitting is properly tightened onto this fitting. When the compression fitting nut is bottomed out and finger tight turn the nut 1 ½ more turns. This is properly tightened.

WARNING: Use only PTFE Teflon, FEP Teflon, or other equivalent tubing approved for high concentration ozone. Use only Kynar, stainless steel, or other equivalent fittings approved for high concentration ozone. Using inadequate tubing or fittings will result in an ozone leak. Excessive ozone leakage may cause property damage, personal injury or death.

TS-40 Initial Startup Procedure

1. Set all switches on the TS-40 to the OFF position.

2. Ensure that all electrical connections & ozone tubing connections are complete.

3. Set the MAIN switch to RUN.

    - The Oxygen Concentrator inside the TS-40 will start.
    - AIR PRESSURE and O2 PRESSURE gauges on the TS-40 will indicate increasing pressures as the Oxygen Concentrator starts.

4. Check all external ozone tubing connections for possible leaks or restrictions.

5. Observe the O2 FLOW and O2 PRESSURE on the TS-40 while it is running. Ensure that any ancillary equipment connected to the TS-40 is also running. Pressure will decrease slightly (1-2 PSI) after the TS-40 has run for about 10 minutes, as the Air Compressor warms up. Adjust flow (via internal stainless steel needle valve) in order to maintain flow & pressure within the following range:

    - O2 PRESSURE 10 to 15 PSI
    - O2 FLOW 1 to 10 LPM

    NOTE: Exact flow and pressure are not critical for initial setup purposes.

    Make adjustments slowly, allowing oxygen (O2) pressure & flow to stabilize between adjustments. Oxygen (O2) pressure & flow will fluctuate slightly during normal operation, this is normal.

6. Once the oxygen flow is properly adjusted, the AIR PRESSURE gauge will continuously cycle between 15 and 40 PSI. This is due to cycling of the Oxygen Concentrator, and is normal expected operation.

7. Turn the O3 GEN switch on the TS-40 to ON. After a 2-3 second delay, the Ozone Generator will start and the O3 GEN light will illuminate.

8. Ozone is now being generated and exiting the OZONE OUT port at the flow & pressure indicated by the O2 FLOW meter and O2 PRESSURE gauge.

Operation

OXYGEN CONCENTRATOR (MAIN)

Operation

The Oxygen Concentrator uses ambient air to produce approximately 93% oxygen. It is of "molecular sieve bed" type construction and uses Zeolite absorption material with pressure swing absorption to remove the nitrogen from the air, leaving approximately 93% oxygen and approximately 7% other gases.

Oxygen Concentrator flow & pressure can be adjusted using the external Ozone Flow Control device. Optimum flow & pressure can be determined according to the "Ozone Generator Production" charts in the "Introduction" section of this manual. Generally, flow and pressure should be held within the following ranges:

- The **AIR PRESSURE** gauge indicates the pressure of air entering the molecular sieve beds. The air pressure will vary **between 15 and 40 PSI** as the sieve beds purge & regenerate in a constant cycle.
- The **O2 PRESSURE** gauge indicates the pressure of oxygen leaving the Concentrator. The O2 PRESSURE gauge will normally read much lower than the AIR PRESSURE and should be somewhat steady, reading between **8 and 20 PSI** under normal system operation.
- The **O2 FLOW** flowmeter indicates the flowrate of oxygen leaving the Oxygen Concentrator and passing through the Ozone Generator. The O2 FLOW should be held between **1 and 10 LPM.** The flowmeter is under pressure and displays "indicated" flow, not "actual" flow. O2 PRESSURE and the "indicated" O2 FLOW should be entered into the following formula to determine "actual" (corrected) flow:

$$\left(\ actualflow \ \right) = \left(indicatedflow \right) x \sqrt{\frac{oxygenpressure + 14.7}{14.7}}$$

Normal Operation: Normally the TS-40 will operate as follows:

- **Air pressure:** 25-45 PSI
- **Oxygen Pressure:** 15 PSI
- **Oxygen Flow:** 7 LPM measured flow

NOTE: Lower than normal AIR PRESSURE or O2 PRESSURE is usually a sign of improper system setup (too much oxygen/ozone flow) or Air Compressor wear. The Oxygen Concentrator will rarely cause low pressure issues. For more information on low pressure issues see the "Maintenance & Troubleshooting" sections of this manual.

Control

The MAIN switch starts and stops the Oxygen Concentrator. When the Oxygen Concentrator starts, you will hear the Air Compressor start running and shortly thereafter you may hear the Oxygen Concentrator cycling as it purges effluent from the sieve beds.

> **NOTE:** The Air Compressor will not start under pressure. Generally, if any amount of pressure is indicated on the AIR PRESSURE gauge the compressor will not start. The Air Compressor is equipped with an automatic thermal overload, and once the air pressure subsides and the motor is cool the compressor will automatically restart. This should take less than 1 minute, and is the normal expected operation of this equipment.

OZONE GENERATOR

Operation

The Ozone Generator is designed to produce ozone from oxygen under pressure. While maximum ozone production will be achieved at higher pressures and flows, the Oxygen Concentrator is limited to a given pressure at a given flow. Optimum flow & pressure can be determined according to the "Ozone Generator Production" charts in the "Introduction" section of this manual.

Control

The Ozone Generator (O3 GEN) will only start when the Oxygen Concentrator (MAIN) is ON. Turn the O3 GEN switch to ON to start the Ozone Generator. Ozone Generator can be turned off by turning the O3 GEN switch to OFF, or by turning the MAIN switch to OFF (shuts down TS-40 entirely).

O3 GEN Light

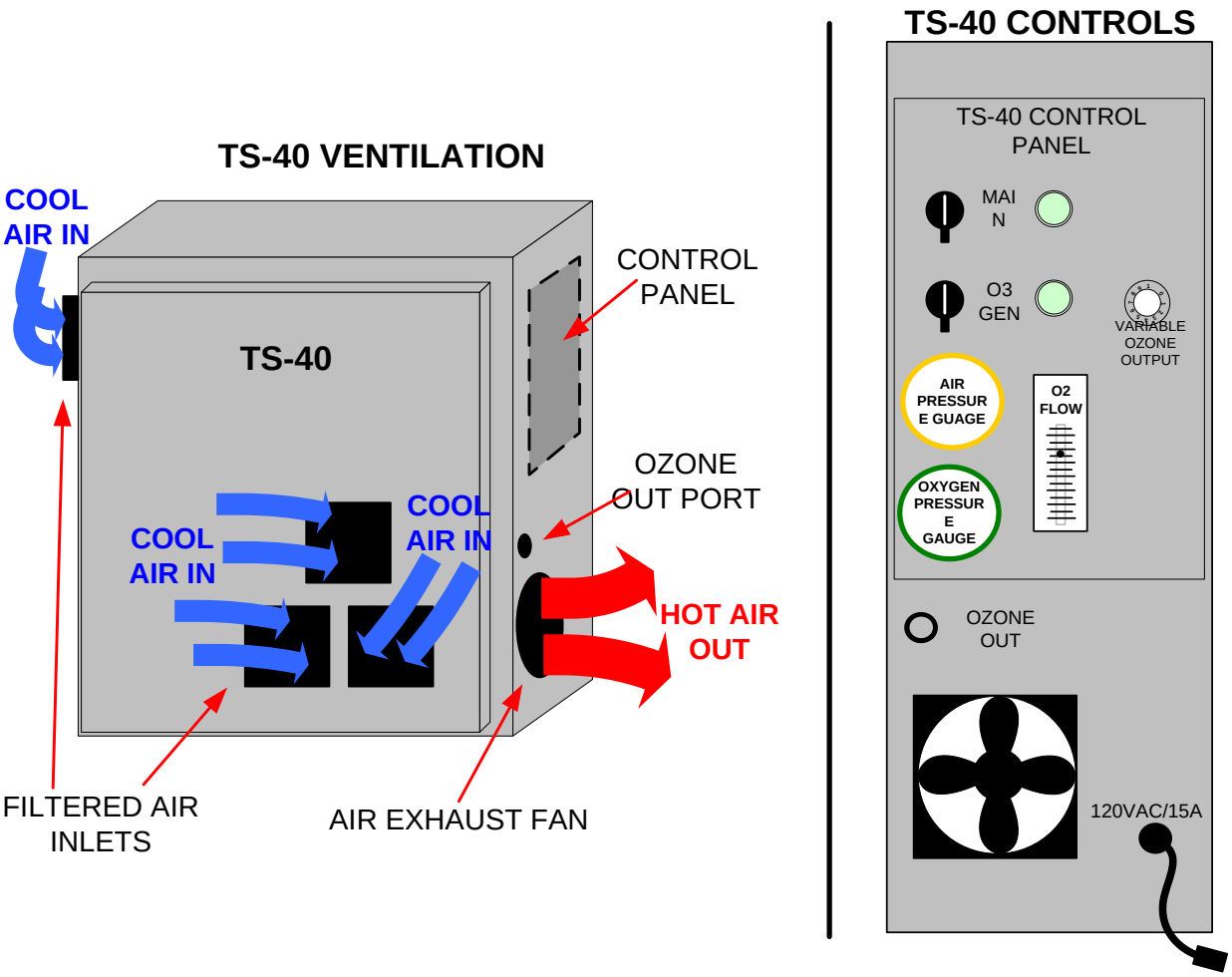
- **ON –** Ozone Generator is on
- **OFF –** Ozone Generator is off due to O3 GEN switch off or externally connected switch off.
- **FLASHING –** Ozone Generator is off due to "OZONE LEVEL MONITOR CONTROL" external connection off.

Variable Ozone Output 0-100%

The TS-40 is equipped with a Variable Ozone Output. The OZONE OUTPUT 0-100% knob on the control panel of the TS-40 will adjust the output of the Ozone Generator from 0 to 100% of the maximum ozone output. The control varies the power level to the ozone generation cell and only affects ozone concentration, it does not affect pressure or flow.

A setting of "0" on the knob will yield zero ozone output, while a setting of "10" will yield 100% of the Ozone Generator's maximum output

TS-40 VENTILATION AND CONTROLS DIAGRAMS



Maintenance Schedule

1. **DAILY**
    a. Check cooling fan on the side of the TS-40 (1 large fan) and inside on the Ozone Generator (2 fans) while the system is running. The fans should run whenever the Oxygen Concentrator is running.

    b. Check **AIR PRESSURE** gauge. Should read between **15-40 PSI** while system is running after startup. Low air pressure may be a sign incorrect oxygen flow settings, Air Compressor wear or massive air leaks. See also "low oxygen pressure…" below.

    c. Check **O2 PRESSURE** gauge. Should read between **8-20 PSI** while system is running after startup.

        Low oxygen pressure is a sign of either:
        1. Incorrect flow settings,
        2. Air Compressor wear,
        3. Massive oxygen leaks, or
        4. Oxygen Concentrators sieve beds needing replacement.

2. **WEEKLY:** Check condition of cooling air inlet filters – 1 on left hand side of the TS-40 and 3 on the front door of the TS-40. Clean or replace as necessary when a layer of dirt is visible on the filter.

3. **EVERY 2 YEARS:** The Zeolite absorption material inside of the Oxygen Concentrator needs to be replaced every 2 years. The Zeolite absorption material (replacement sieve beds) can be obtained from Ozone Solutions. Adverse conditions may cause premature contamination of the Zeolite. Adverse conditions include:

    - Ambient **heat and humidity** levels above the recommended levels described in the "Installation" and "Specification" sections of this manual.
    - Extended periods of **low air pressure** while the system is running.
    - Extended periods of **oxygen flow above 10 LPM**.

4. **EVERY 8000 HOURS:** The Air Compressor will need to be rebuilt approximately every 8000 hours of use. If there are repeated AIR PRESSURE LOW or O2 PRESSURE LOW alarms and no other problems can be found, the Air Compressor may need rebuilding. Parts for this Maintenance can be obtained from Ozone Solutions.

Specifications

Maximum Ozone Production: 40 g/h at 10 LPM
Maximum Ozone Pressure/Flow: 15 PSI at 10 LPM flow

Environment:
Operating Temperature: 40°F to 95°F
Operating Humidity: 85% RH maximum, non-condensing
Storage Temperature: -10°F to 150°F
Storage Humidity: non-condensing

Electrical Requirements:
Operating Voltage: 120
Full Load Amps: 10
Maximum Starting Current: 20 Amps
Power Consumption: 1200 Watts

How to Contact Ozone Solutions

By mail:
Ozone Solutions, Inc.
451 Black Forest Rd
Hull, IA 51239

By telephone: (712) 439-6880
By fax: (712) 439-6733

By e-mail: **info@ozonesolutions.com**

11-06

ECO SENSORS, INC.
OZONE SWITCH tm
Model OS-4

INSTRUCTIONS FOR USE

OS-4 Host Unit

SM-4 Sensor Module

GENERAL

The model OS-4 acts like a thermostat to control ozone generators and alarms based on sensing two set-points of ozone concentrations: one to turn on the generator or alarm and the other to turn it off. There is also a .1 ppm alarm for continuous monitoring of human safety in the vicinity of the sensor. The standard available range is .05-20 ppm. The SPDT relay contacts handle up

to 5 amps at 250 volts. The OS-4 also has digital, voltage and 4-20 mA outputs to drive remote monitors and control systems. The OS-4 should not be used in the presence of acid gases, strong VOC's, strong halogen fumes, silicones or sulfur compounds.

Do not open or service the sensor module when any power is connected to the OS-4 or its sensor module. This will damage the sensor calibration memory.

The instrument is conditionally warranted for one year. Save a copy of your purchase document as a proof of purchase and date, and read the warranty statement at the end of this manual.

OPERATION

First, verify that the instrument is working as received. Verify that a sensor module is wired to the OS-4 main instrument processor. The other terminal blocks and set-point controls are found on the inside back of the instrument (remove cover to access them).

Connect your AC adapter to the power jack or your 8-24 VDC supply to terminals + and GND of the terminal block TB4. The green LED **Power** indicator should light and digits should show on the display. The power light should dim at regular intervals. This signifies that the OS-4 is receiving sample data from the SM-4 sensing module.

In order to burn off any chemicals that the sensor may have absorbed during shipping and storage, you should let the OS-4 run with power on and the sensor module connected for 1 hour before response testing or overnight before the first use on site. It is recommended to test the instrument for positive response with an ozone generator when the instrument is received and again at the site where the instrument is installed. Eco Sensors, Inc. offers an inexpensive hand-held ozone generator for this test purpose, the model OG-1AC.

You can now connect the Ozone Switch ™ to an external device such as an ozone generator, alarm or PLC. See OUTPUTS TO EXTERNAL EQUIPMENT below. Bring the external wiring through the access hole on the bottom of the enclosure.

CALIBRATION

The OS-4 uses a calibration concept that is somewhat novel: The ozone sensor is mounted on a sensing board, called the SM-X, includes a microprocessor and EEPROM memory. The exact calibration curve for that particular ozone sensor is burned into the EEPROM. The OS-4 host instrument adjusts the sensor readings for temperature and relative humidity based on data sent from the sensor module. The SM-X sensor board is disposable or recalibratable based on the user's cost and time-out-of service considerations, and it plugs into a larger board in a small enclosure called the SM-4 module which can be up to 30 meters (100 feet) from the OS-4.

In most cases, it is probably cheaper and faster to replace the SM-X sensor board with a freshly calibrated one than to send the current old one back for recalibration. Also the SM-X board can NOT be recalibrated in the field. It can only be done by a special computer at Eco Sensors, Inc.

The SM-X calibration can be checked by the Eco Sensors OG-3 calibration checker. The calibration is within 15% over the sensor's range.

OUTPUTS TO EXTERNAL EQUIPMENT

The OS-4 has a variety of outputs to external equipment. Referring to the terminal blocks accessed by opening the instrument's cover panel, these are:

1 - SAFETY LIMIT OF .1 PPM EXCEEDED IN SENSOR AREA. Internal relay connected to TB2 is activated and panel yellow LED comes on. The relay has 5 A 250 volt rated contacts.

2 - RELAY (USUALLY CONTROLLING AN OZONE GENERATOR): Normally open and normally closed contacts accessed on TB1. The set points for this relay are labeled HIGH LIMIT and LOW LIMIT. The HIGH LIMIT **must always be greater than** LOW LIMIT **and the low limit should always be above 0.** The red LED illuminates when the OS-4 receives power indicating that the generator controlled by the OS-4 is receiving power. This red LED stays on until the ozone generator produces enough ozone to reach the upper limit set point setting. The red LED will not illuminate again until the ozone generator turns on again when the ozone concentration falls below the lower limit set point. This relay has 5 A 250 volt contacts. It is recommended that for all but the smallest generators that this relay control a larger power-handling relay located in the generator power wiring area.

3 - RS-232 OUTPUT DATA.

4 - ANALOG OUTPUT (VOLTAGE). Gnd and 0-2 terminals on TB3. Usually for driving small data loggers.

5 - ANALOG OUTPUT (4-20 MA). Gnd and 4-20 on TB3. Usually for driving a PLC (programmable logic controller) system controller.

SERVICE AND MAINTENANCE

Do not attempt to do board level repairs or microprocessor programming yourself. This will void the warranty. We recommend checking the calibration monthly and replacing the sensor module annually. General repairs should be done at the factory or by an Eco Sensors authorized service representative.

Calibration of the sensor on its board (SM-X) is done by computer in a special laboratory at the factory. Therefore in most cases it is lowest cost to replace the SM-X board than to request that it be recalibrated.

Instruments with problems during the warranty period should be returned as system (OS-4 and SM-4) to the factory or authorized service representative for diagnosis and repair.

AC ADAPTER

For use in 120 V 60 HZ areas, the Eco Sensors P-20 adapter should be used. For other areas adapters should be purchased local that fit local wall sockets and conform to local codes. The output should be 12 volts DC unregulated, 300-500 mA. The plug to our instrument should fit a 5.5/2.5 mm socket with the center pin +. For further details see our Tech Note P-101.

SPECIFICATIONS

Sensor: Heated metal oxide semiconductor.
Sensitivity: First responds at .05 ppm

Response time: Within one minute of when gas reaches the sensor.
Temperature and humidity range: 0-40 deg C and 0-80% relative humidity.
Supply voltage required: 8-24 volts DC, 300 mA. Ground -.
Adapter plug: 5.5 mm/2.5 mm female, center +.
Size of instrument: 128 (H) X 64 (W) X 42 mm (D) (5.03" X 2.52" X 1.65").
Weight of instrument: 200 grams (7 oz.).
Size of SM-4 Sensor Module 76 mm (H) X 64 mm (W) X 29 mm (D) (3.00" X 2.50" X 1.12")
Horizontal mounting centers: 73 mm (2.87")
Cable from SM-4 sensor module to OS-4 instrument host unit: Up to 100 meters (390 feet) 3 conductor cable such as used for indoor telephone wiring. Wires preferably are color coded red, black and white to correspond with the terminal block notations. The conductors should be as large as possible to reduce resistance loss.

SAFETY FEATURES

Human safety alert: LED illuminates and a relay is activated if sensor is in >.1 ppm ozone.
Loss of power protection: Relay opens (shuts off generator) when the instrument loses power.
Enclosure: Self-extinguishing ABS plastic. *Relays:* UL, CSA and CE approved.
Sensor: Heated element is flame arrestor protected.
Electrical: (a) Circuits operate at 12-24 volts (b) Self-resetting fuse to protect against excess input current flow. (d) Overvoltage protection diode barrier to protect against supply voltage surges, spikes, overvoltage, and reverse polarities.

PRECAUTIONS

- Do not open or service the sensor module or board with power connected to either the OS-4 or the sensor module.
- Allow at least 1-4 hours warm-up for functionality testing and 24 hours warm-up for operational use.
- Read all instructions in this manual.
- Keep instrument dry. Never let water or other liquids into the sensor.
- Do not drop the instrument or subject it to continuous vibration.
- Do not store in high levels of dust.
- Do not clean the instrument with cleaning chemicals or solvents. Clean it with a damp cloth.
- Do not operate near heavy aerosols (spray) usage or where oxygen is being administered.
- Call a qualified electrician if you have any doubts about voltages, currents, electrical practice, etc.
- Do not operate the instrument or rely on its readings where there are high concentrations of:
  - Chlorine or other halogen compounds
  - Sulfur compounds
  - Strong VOCs such as solvent vapors.
  - Silicone compounds such as RTV.
  - Urine residues and ammonia compounds
  - Acid gases such as sulfuric acid or nitric acid fumes.
- Keep at least a meter above fruit in food storage applications to avoid the negative influence of ethylene ripening agent emitting from the fruit.

When in doubt, operate the instrument in your worst case conditions for at least 24 hours to see if it will operate properly.

WARRANTY

This product is warranted against defects in materials and workmanship for one year following the date of purchase by the original owner. This warranty does not include damage to the product as a result of misuse, accident, damage, modifications or alterations, and it does not apply if the instructions in this manual are not followed.

If a defect develops during the warranty period, Eco Sensors at its election will repair the instrument or replace it with a new or reconditioned model of equivalent quality. In the event of replacement with a new or reconditioned instrument, the replacement unit will continue the warranty of the original unit.

If the product should become defective during the warranty period, please return it through your distributor, or call Eco Sensors at (800) 472-6626 or e-mail at sales@ecosensors.com to receive return instructions and a Return Goods Authorization (RGA) number.

Except as provided herein, Eco Sensors makes no warranties, express or implied, including warranties of merchantibility and fitness for a particular purpose. Eco Sensors shall not be liable for loss of use of this instrument or other incidental or consequential damages, expenses or economic loss, or claims for such damage or economic loss.

This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

RECORD YOUR SERIAL NUMBER HERE_____

KEEP THIS MANUAL AND WARRANTY FOR YOUR RECORDS.

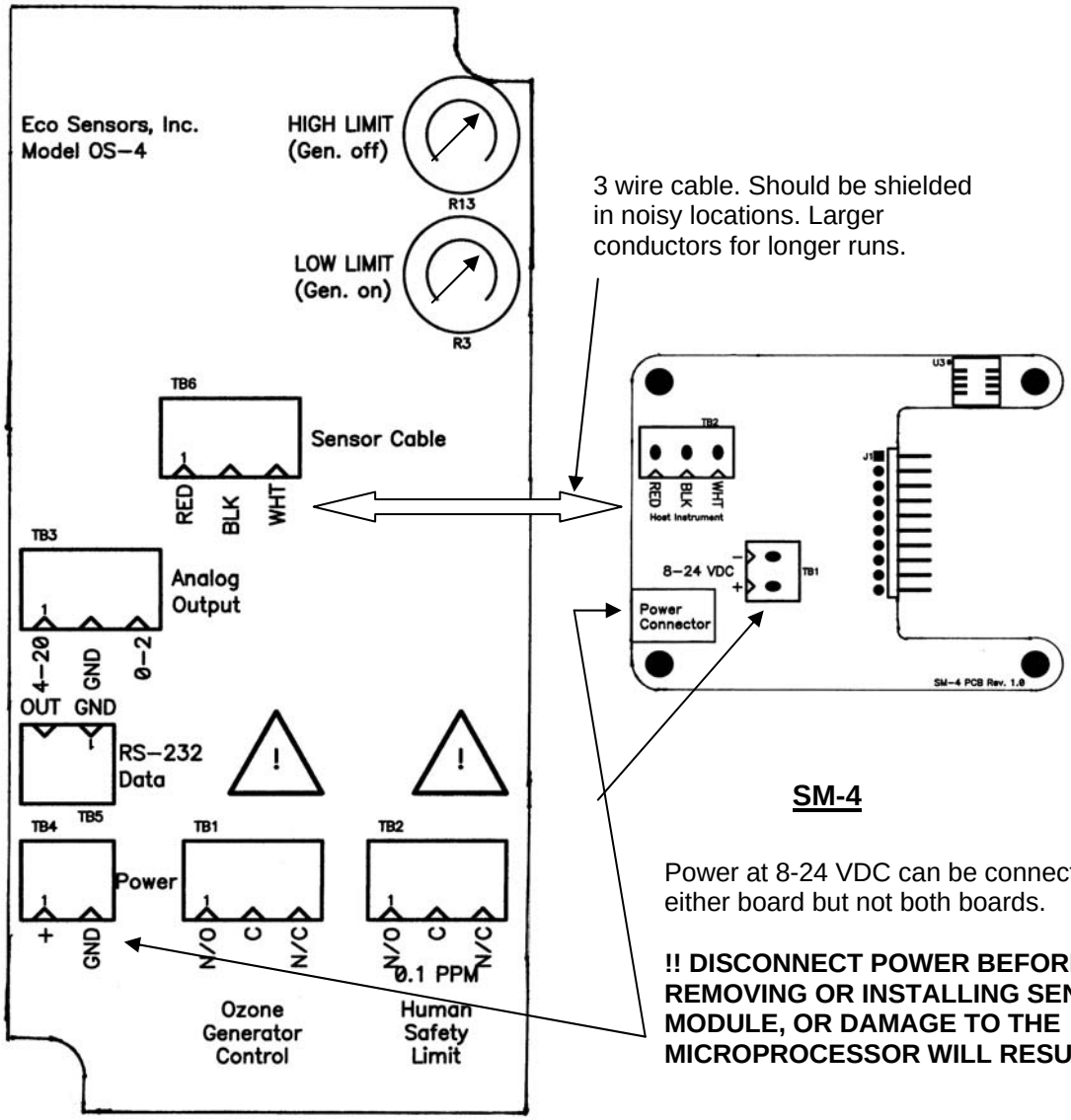
Eco Sensors is a registered trademark of Eco Sensors, Inc.

For brochures, application and tech notes, and other useful information, visit our extensive website at www.ecosensors.com. E-mail us at sales@ecosensors.com.

APPENDIX A

WIRING TO THE OS-4 HOST PROCESSOR

AND THE SM-4 REMOTE SENSOR MODULE



SM-4

Power at 8-24 VDC can be connected at either board but not both boards.

!! DISCONNECT POWER BEFORE REMOVING OR INSTALLING SENSOR MODULE, OR DAMAGE TO THE MICROPROCESSOR WILL RESULT !!

OS-4

APPENDIX B

REPLACING THE SENSOR MODULE

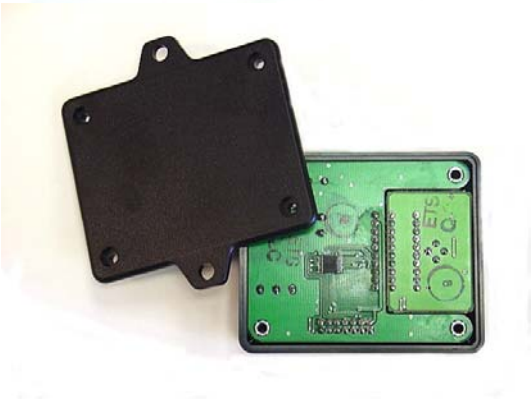
1- Locate SM-4 sensor module and put on workbench.

Sensor mounting centers are 23 mm (2 7/8")

IMPORTANT!!

2 - **Disconnect power cable at OS-4 or SM-4 (wherever it is connected).**

3 - Remove back cover.



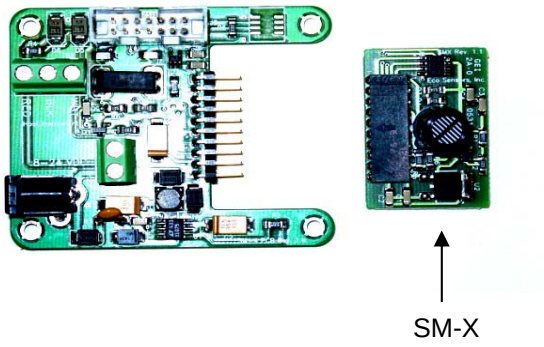
4 - Examine SM-4 board.

5 - Check for tight connections at the terminal block.

+8-24V Red Gnd Black Signal White

Terminal block and power jack for powering at sensor module end instead of OS-4

6 - Carefully replace SM-X sensor module. Reassemble SM-4 module. Connect power.



SM-X

ES-600 Ozone Controller Operation Manual

Questions about your product?
Find answers here:

Web: www.ozonesolutions.com/ES-600
Phone: 712-439-6880

Ozone Solutions
OZONE CONTROLLER
Model ES-600
Instructions for Use

General and New Features

The ES-600 is an industrial grade Ozone controller and monitor. The ES-600 design has been optimized for accuracy, ease of installation, setup and operation:

- All connections and controls are on the front to allow mounting of the unit before setup.
- Rugged, splash resistant enclosure and connectors for industrial environments.
- Set points for Ozone control relays are digitally controlled and are set to numeric values. This makes precise Ozone control easy to set up, even if Ozone is not currently present.
- Front panel indicator lights display a variety of important Ozone control parameters including when level exceeds 0.1ppm OSHA limit.
- Generator Control “enable” allows for disabling the generator for maintenance at the ES-600 panel.
- User selectable ranges for analog outputs (4-20 mA and 0-2 VDC)
- Full digital display.

Initial Operation

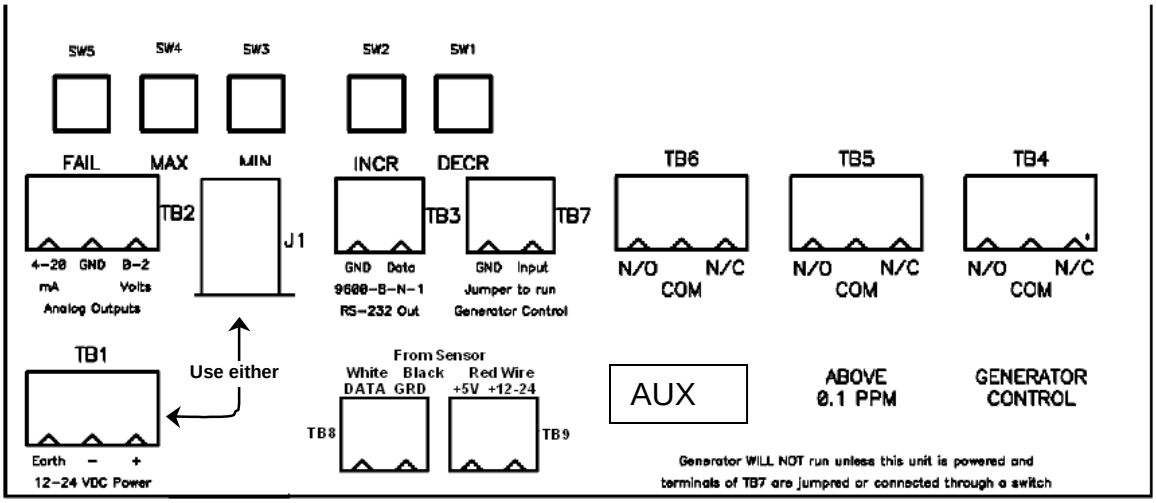
All connections between the ES-600 and the SM-4 sensor unit are made at the factory. Connect the P20 power adaptor included (US, Canada and Mexico only) or your 8-24 VDC supply to terminals + and - of the terminal block TB1. The green LED Power indicator should light and then begin blinking at 1-second intervals and Digits should show on the display. This indicates that the ES-600 is receiving sample data from the SM-4 sensing module.

Warm-up

In order to burn off any chemicals that the sensor may have absorbed during shipping and storage, you should let the ES-600 run with power on and the sensor module connected for 1 hour before response testing or overnight before the first use on site. We recommend testing the instrument for positive response with an ozone generator when the instrument is received and again at the site where the instrument is installed.

External Outputs

Terminal Blocks listed in order and descriptions.



- **TB1: 12-24 VDC POWER:** Power input and earth grounding for the ES-600
- **TB2: ANALOG OUTPUT:** 4-20mA and 0-2 VDC to external control equipment. See “Analog Range Selection” section for range setup options. Default range is 0-20 PPM. [**NOTE**: the 4-20 mA output is a DRIVER rather than a current-sink type output.]
- **TB3: RS-232 OUT:** Serial data output. Refer to “Data Connection” instructions for details.
- **TB4: GENERATOR CONTROL:** User adjustable relay to turn off or on equipment.
- **TB5: ABOVE 0.1 PPM:** Relay tied to OSHA human safety limit.
- **TB6: USER-ADJUSTABLE:** User adjustable alarm relay
- **TB7: GENERATOR ENABLE:** Jumper to enable generator control. Remove to perform maintenance on the generator components. If these terminals are not connected, the generator will never run
- **TB8: Sensor Data and Ground:** Run cable from **SM-4 TB-1** Blk (grd) and WHT (data) to TB8
- **TB9: SENSOR POWER:** Power to sensor. Connect Red wire either from:
    - **+5V out** to **SM-**4 **TB1 +5V OR**
    - **+12-24V out** to **SM-4 TB2 12-24V+**

Do not connect ‘+12-24 Out’ terminal on the ES-600 to the SM-4 TB1 ‘+5V’. This will damage the SM-4! The +12-24 terminal is in place to power the SM-4 over long cable lengths. Normally, the SM-4 will be shipped with a 6’ 3-wire cable connect to TB1 +5V, BLK (grd) and WHT (data).

Indicator Lights and Display

- **Ozone:** Auto ranging digital display in PPM (Parts per Million)
- **Control Relay High:** On when Ozone reading above the upper set point
- **Sensor OK:** Blinks at 1-second intervals when receiving data from Sensor.
- **Control Relay Low:** On when Ozone reading below the lower set point.
- **Aux. Relay:** User-adjustable alarm relay.
- **Safety Relay:** On when reading exceeds 0.1 PPM (OSHA safety limit)
- **Control Relay:** On when relay is controlling Ozone.

Data Connection

The serial digital data stream from the SM-4 is also available for connection to a computer. Data is sent at 1-second intervals. The parameters are: **9600 bps, 8 data bits, Parity: None, Stop bits: 1, Flow Control: None**

Output example at 1PPM: Ozone, (PPB) Temperature, (Celsius) and Relative Humidity:

1000, 24, 34
1000, 23, 33

AC Adapter

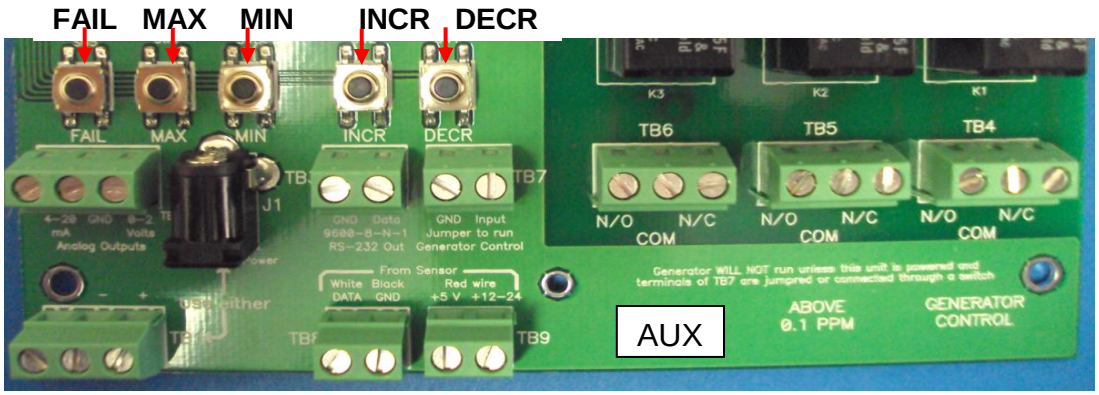
For 120 V 60 HZ areas, the Ozone Solutions P-20 adapter should be used (included with device). For all other areas, adapters should be purchased locally that fit local wall sockets and conform to local codes. The output should be 12 volts DC unregulated, 300-500 mA. The plug to our instrument should fit a 5.5/2.5 mm socket with the center pin +.

Set Point and Alarm Condition Adjustment

Five push-buttons are mounted on the circuit board behind the wiring compartment cover. Remove cover (two screws) and locate the buttons in the upper-left corner. From left to right, they are: FAIL, MAX, MIN, INCR and DECR.

FAIL: Time (in minutes) ozone level may remain above MAX set point or below MIN set point before the "Unable to control" indicator and relay are switched on.

MAX: Maximum ozone set point, at which the generator is turned off.



MIN: Minimum ozone set point, at which the generator is turned off.

INCR: Increase set point value.

DECR: Decrease set point value.

Select the set point to change by holding down one of the first three buttons. The current value of that set point will appear on the display while the button is pressed. Press the INCR or DECR button to adjust the value. Note that MIN will not adjust higher than MAX (and vice-versa).

To adjust AUX Relay (TB6) set point:

1. Remove bottom front panel.
2. Locate 5 black buttons on the left side of the board
3. Press and hold the FAIL button. The audible alarm should sound, and the digital display will show the alarm set-point.
4. If you would like to move the set-point up, continue holding down the FAIL button. At the same time, push the INCR button until the desired set-point is reached, as indicated on the digital display.
5. If you would like to move the set-point down, continue holding down the FAIL button. At the same time, push the DECR button until the desired set-point is reached, as indicated on the digital display.
6. Replace front panel.

Analog Range Selection

Full-scale ranges for the 0-2 Volt and 4-20 mA analog outputs may be selected by adding or removing up to three push-on jumpers on header J4, which is located on the back of the display circuit board. Access this area by removing four screws from the display bezel.

Jumpers	A	B	C	Range selected
	OFF	OFF	OFF	0-2 PPM
	ON	OFF	OFF	0-5 PPM
	OFF	ON	OFF	0-10 PPM
	ON	ON	OFF	0-20 PPM

ON	OFF	ON	0-50 PPM
ON	OFF	ON	0-100 PPM
OFF	ON	ON	0-200 PPM
ON	ON	ON	0-500 PPM

IMPORTANT NOTE: The range of an ES-600 is limited by the sensor module. The currently available SM-4 operates from 0-20 PPM. Higher ranges may be available on future sensor modules. Please contact Ozone Solutions for details.

Specifications

Wall mounted polycarbonate enclosure resists water spray and splash (NEMA 4X).
Size: H = 6.3”/160mm, W = 6.5”/166mm, D = 4.6”/118mm.
Wiring: Conduit or cable gland knock-outs along bottom of enclosure.
Power in: 12-24 VDC.
Power out: +5 or +12-24 VDC to sensor.
Data in: RS-232 serial data from remote sensor module (SM-4 or equivalent).
Data out: RS-232, 9600 Baud 8N1 format.
Analog out: 0-2 V and 4-20 mA, full scale range settable by internal jumpers.
Control in: Generator enable (contact closure).
Control outputs: Relays, 10A @ 25VDC, 0.25A @ 250VDC, 2.0 KVA AC (resistor).
Relay functions: Ozone generator control, >100 PPB safety limit, failure to control.
User controls (internal): MAX setpoint, MIN setpoint, FAIL time, increase, decrease.
Numeric display: Four digits, 0.5”/12mm, auto-ranging, with backlight.
LED indicators: Sensor, above MAX, below MIN, >100 PPB, generator on, failure.

Service and Maintenance

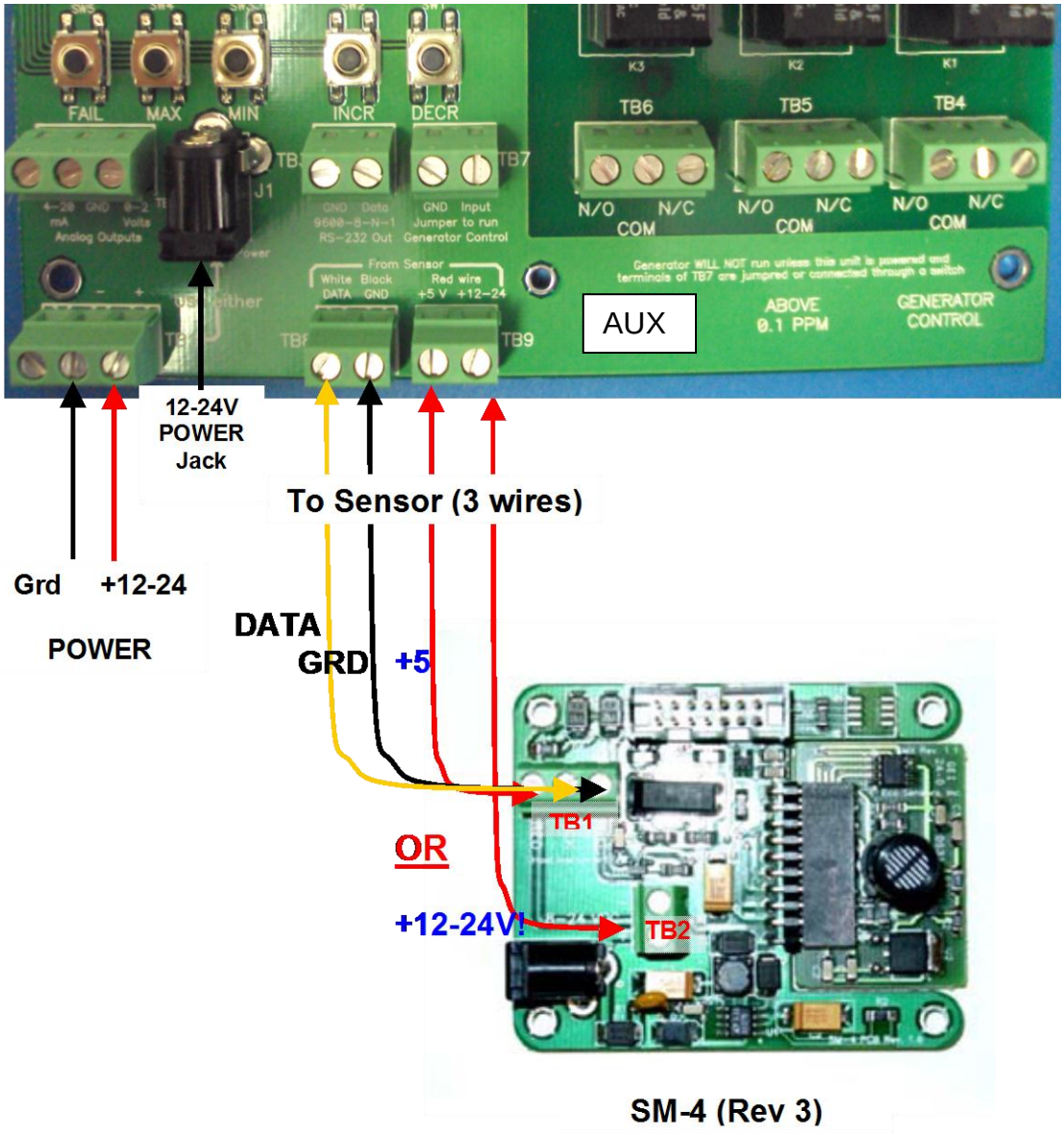
Do not attempt to perform board level repairs or microprocessor programming. This will void the warranty. We recommend checking the calibration monthly and replacing the sensor module annually. The unit should be returned to Ozone Solutions for repairs. **Tampering with or attempting repairs to the unit will void the warranty.**

Calibration of the sensor on its board (SM-X) is done electronically in a specially constructed facility at the factory. Therefore it is more cost effective to replace the SM-X board than to request that it be recalibrated.

Instruments with problems during the warranty period should be returned as a system (ES-600 and SM-4) to Ozone Solutions for diagnosis and repair. Call to coordinate a Return Materials Authorization (RMA).

Appendix A:

Wiring Illustration (ES-600 Rev 4.0):



APPENDIX B

CONNECTING ES-600 RS232 OUTPUT TO COMPUTER

Connections:

The connections from the ES-600 to the serial COM port of a PC are as follows:

ES-600 TB3		COM port DB9 Connector
Data Out	⟷	Pin 2 RxD
GND	⟷	Pin 5 SGND

The output data stream is OUTPUT ONLY at 1-second intervals. There is no input from the PC to the ES-600.

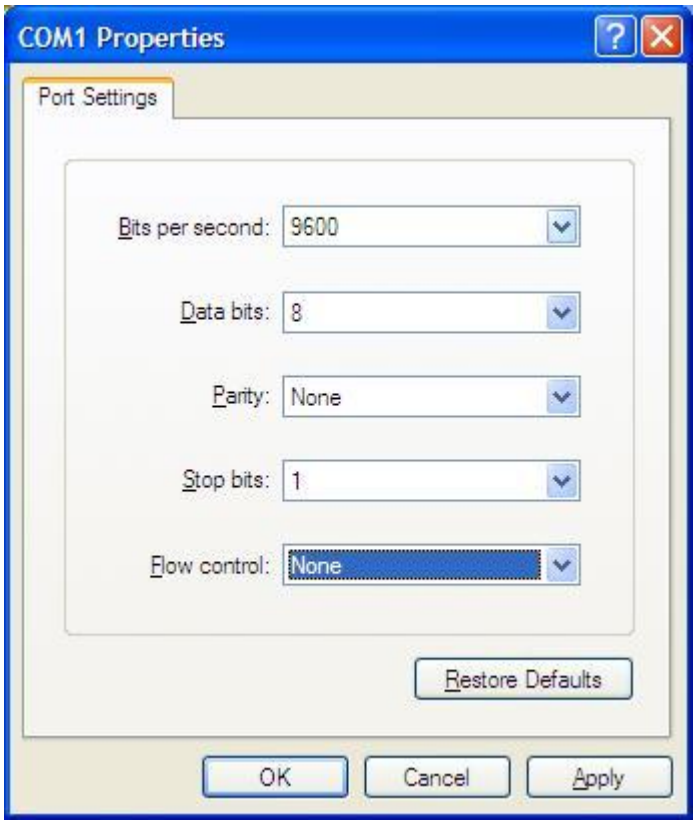
Example Terminal Setup in Windows

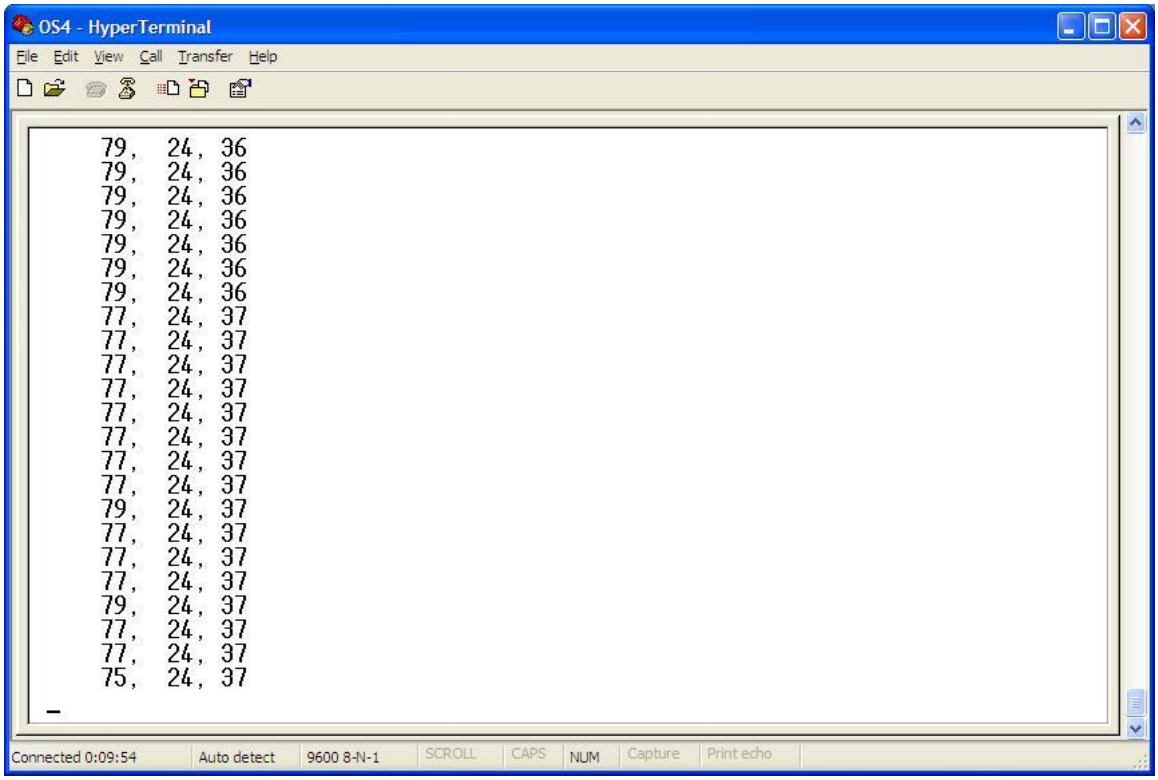
The terminal program in Windows is HyperTerminal. It is located in **Start>>All Programs>>Accessories>>HyperTerminal**

1. Open HyperTerminal

2. Enter COM port to be used:

3. Enter the serial communications parameters as shown:



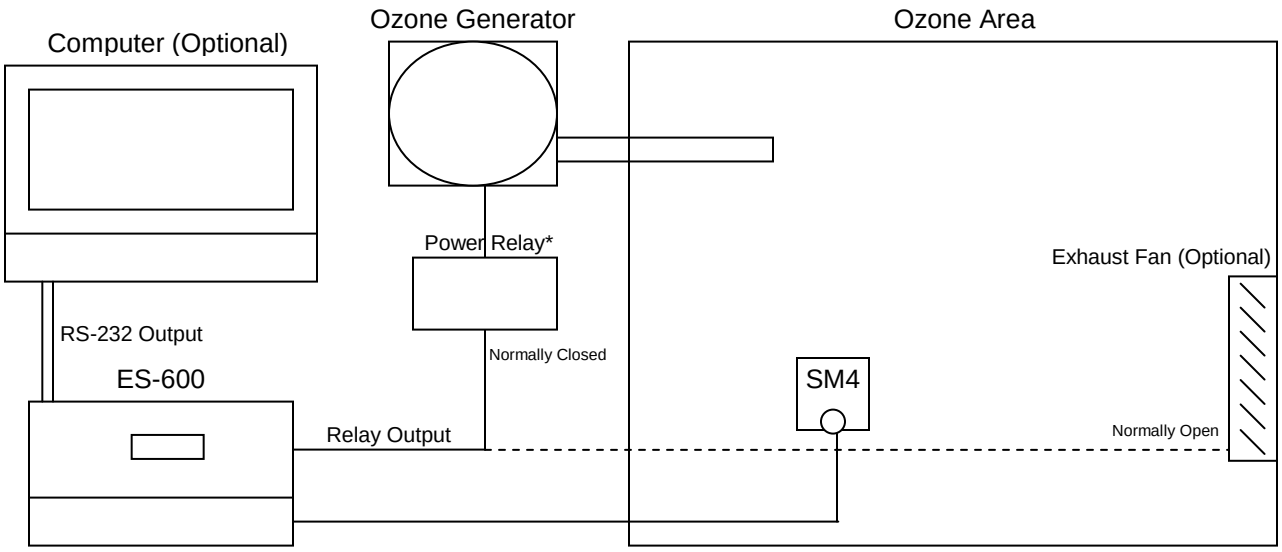


Output shown: 0.079PPM (79 ppbv), 24 degrees C, 37% Relative Humidity. The ES-600 outputs one data point every second.

Appendix C

Typical ES-600 Application Diagram

(For reference purposes only)



*Power relay is required if Ozone generator load exceeds ES-600 relay

WARRANTY

This product is warranted against defects in materials and workmanship for one year following the date of purchase by the original owner. This warranty does not include damage to the product that results from misuse, accident, dropping, modifications or alterations, and it does not apply if the instructions in this manual are not followed, or if the unit is otherwise used outside its intended specifications.

If a defect develops during the warranty period, Ozone Solutions, in its sole discretion, will repair the instrument or replace it with a new or reconditioned model of equivalent quality. In the event of replacement with a new or reconditioned instrument, the replacement unit will continue the warranty of the original unit.

If the product should become defective during the warranty period, please return it through Ozone Solutions at (712) 449-6880 or e-mail at sales@ozonesolutions.com to receive return instructions and a Return Materials Authorization (RMA) number.

Except as provided herein, Ozone Solutions makes no warranties, express or implied, including warranties of merchantability and fitness for a particular purpose. Ozone Solutions shall not be liable for loss of use of this instrument or other incidental or consequential damages, expenses or economic loss, or claims for such damage or economic loss.

RECORD YOUR SERIAL NUMBER HERE_____

KEEP THIS MANUAL AND WARRANTY FOR YOUR RECORDS.

URS

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
PFIZER	HANNIBAL, MISSOURI	16170731

Photo No.	Date:
1	03-12-13

Description:

IGTS Building. View looking north.

Photo No.	Date:
2	03-12-13

Description:

Ozone generator mounted in IGTS building.

URS

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
PFIZER	HANNIBAL, MISSOURI	16170731

Photo No.	Date:
3	03-12-13

Description:

Ozone diffuser.

Photo No.	Date:
4	03-12-13

Description:

"T" in influent piping for the ozone diffuser.

URS

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
PFIZER	HANNIBAL, MISSOURI	16170731

Photo No.	Date:
5	03-12-13

Description:

Ozone diffuser installed in “T” along influent stream.

Photo No.	Date:
6	03-11-13

Description:

View of cleaned Air Stipper 1 side wall. Unable to remove orange colored staining.

.

4

URS

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
PFIZER	HANNIBAL, MISSOURI	16170731

Photo No.	Date:
7	03-11-13

Description:

Cleaned interior of air stripper 2. Unable to remove orange colored staining.

Photo No.	Date:
8	03-11-13

Description:

Top of cleaned air stripper tray. Unable to remove orange colored staining.

URS

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
PFIZER	HANNIBAL, MISSOURI	16170731

Photo No.	Date:
9	03-11-13

Description:

Closeup view of cleaned air stripper tray. Unable to remove orange colored staining.

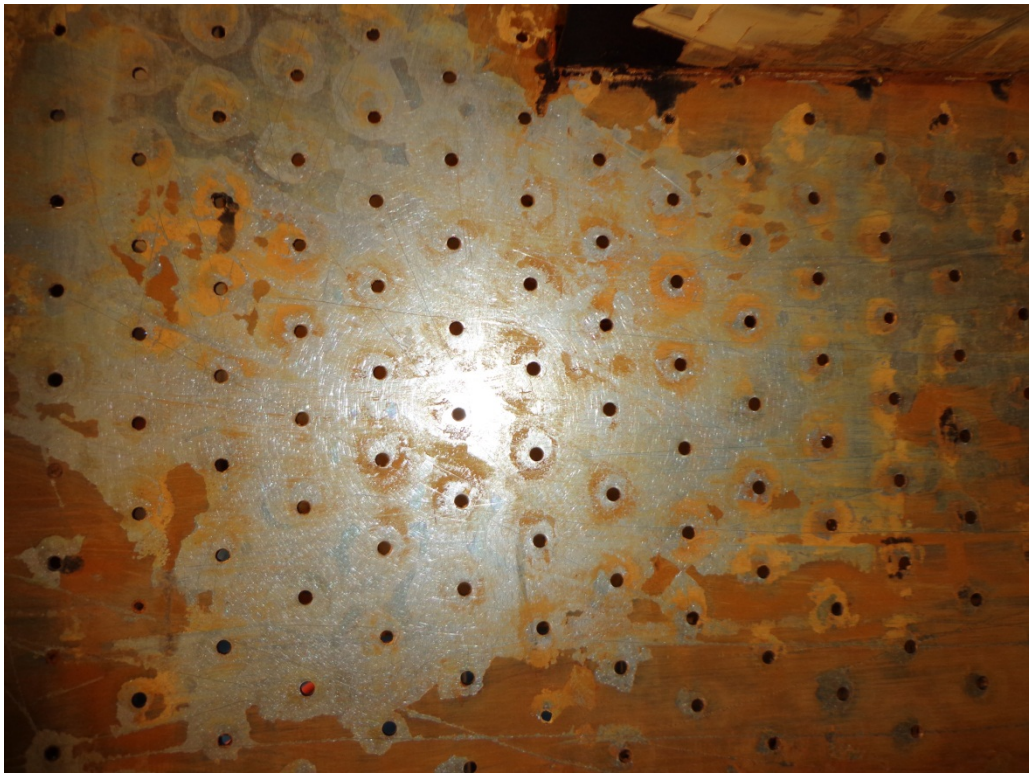


Photo No.	Date:
10	03-12-13

Description:

Ozone detector mounted above personnel entry door.

4

URS

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
PFIZER	HANNIBAL, MISSOURI	16170731

Photo No.	Date:
11	03-12-13

Description:

OS-4 ozone monitor mounted near personnel entry door.

Note: The monitor was removed and replaced with the ES-600 ozone monitor.

Photo No.	Date:
12	04-04-13

Description:

ES-600 monitor that replaced OS-4 monitor.

URS

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
PFIZER	HANNIBAL, MISSOURI	16170731

Photo No.	Date:
13	03-12-13

Description:

View of air stripper 1 while IGTS is running.

Photo No.	Date:
14	07-03-13

Description:

Air stripper tray prior to cleaning event in July 2013. The mass is soft with a liquid/fluff consistency.

URS

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
PFIZER	HANNIBAL, MISSOURI	16170731

Photo No.	Date:
15	09-17-13

Description:

Air stripper tray during cleaning event in September 2013. The mass has same appearance and consistency as before.

Photo No.	Date:
16	09-17-13

Description:

Interior of air stripper with cleaned trays, September 2013 cleaning event.

URS

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
PFIZER	HANNIBAL, MISSOURI	16170731

Photo No.	Date:
17	09-17-13

Description:

Interior of air stripper after September 2013 cleaning event.

Photo No.	Date:
18	09-17-13

Description:

Cleaned sump pit, September 2013 cleaning event.

URS

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
PFIZER	HANNIBAL, MISSOURI	16170731

Photo No.	Date:
19	01-09-13

Description:

View of drainage ditch at outfall location (January 2013).

Photo No.	Date:
20	04-24-13

Description:

Drainage ditch, April 2013.

MEMORANDUM

DATE: July 16, 2013

TO: Mark Kleiman, Quantum Management Group, Inc.

FROM: Brian Wight, URS Corporation

SUBJECT: **Ozone Background Study**
Former ACC Facility, Hannibal, Missouri

PURPOSE

This memorandum documents the ozone background study completed at the former American Cyanamid Chemical (ACC) facility in Hannibal, Missouri (Figure 1). The ozone background study activities were completed on March 21, 2013 and April 4, 2013. The ozone background study was completed to verify the levels of ozone detected within the interim groundwater treatment system (IGTS) building were associated with naturally occurring (background) levels of ozone.

BACKGROUND

Groundwater is extracted from the aquifer by three extraction wells, and conveyed via underground piping to the IGTS building (Figure 2). At the IGTS building, flow and pressure is metered. The water then passes through two air strippers in series where the VOCs are removed from the water. Vapor from the air strippers vents through mist eliminators to the atmosphere. Monitoring of VOCs in treated groundwater is completed hourly using an in-line gas chromatograph (GC) organic vapor analyzer (OVA). The treated effluent is then pumped to a National Pollutant Discharge Elimination System (NPDES) permitted point of discharge located in a drainage ditch, south of the IGTS building.

The current maximum flow rate through the system is 90 gallons per minute (gpm). The system was designed for a rate of 150 gpm. The modeled flow rate for optimum plume containment is 150 gpm. We are currently planning on increasing flow in an incremental manner to reach the design flow rate.

The proposed IGTS pretreatment alternative is ozone. Ozone (sometimes referred to as activated oxygen) is composed of three atoms of oxygen. The third atom of ozone makes it an extremely powerful oxidant and the second most powerful sterilizer in the world. The third oxygen atom readily attaches itself to and destroys other molecules, including the bacteria *Bacillus cereus/thuringiensis* and Gallionella. Once ozone is used, it reverts back to oxygen.

A review of the bacterial analysis of the effluent water indicated elevated total bacterial populations. Of concern is the presence of *Bacillus cereus/thuringiensis* and Gallionella. *Bacillus cereus/thuringiensis* produce a biofilm in order to capture nutrients. Gallionella uses the naturally occurring iron in the groundwater influent as an energy source, and secretes a "slime" that is biofouling and plugging the air stripper trays. To prevent the continued biofouling of the air stripper trays, ozone will be applied to the influent, in the combined header pipe, prior

to the air strippers. The application of ozone to the influent should control the amount of bacteria in the groundwater thus limiting the amount of biofouling occurring in the air strippers.

Ozone Solutions installed an ozone generator, ozone monitor, and ozone dispensing tube on March 12 and 13, 2013. An ozone monitor was mounted near the personnel entry door, on the inside of the building, so that an ozone reading could be made prior to entering the building. The ozone monitor would also shut down the ozone generator once ozone concentrations inside the IGTS building reached 0.10 ppm. The ozone dispensing tube was installed downgradient of the bag filter at a location that has a pressure less than 7 psi.

The IGTS shutdown conditions were tested to confirm that the system shuts down as designed. Elevated levels of ozone (0.08 to 0.14 parts per million (ppm)) were being observed on the ozone monitor mounted near the personnel entry door. Personnel from Ozone Solutions were notified of the elevated readings on March 14, 2013. Ozone Solutions personnel indicated the elevated readings were likely associated with background levels of naturally occurring ozone. Quantum Management Group was notified of the elevated ozone readings on March 14, 2013, and the ozone generator was shut down until it could be confirmed that the elevated levels of ozone observed at the meter were associated with naturally occurring (background) ozone.

OZONE BACKGROUND STUDY ACTIVITES

The ozone background study consisted of the collection of ozone readings outside and inside the IGTS on March 21, 2013 under the following scenarios:

- Ozone generator off, building ventilation off.
- Ozone generator off, building ventilation on.
- Ozone generator on, building ventilation off.
- Ozone generator on, building ventilation on.

Ozone levels were measured in real time utilizing two handheld AeroQual Series 500 Ozone Monitors (see Attachment 1). The AeroQual Series 500 Ozone Monitors were used to measure ozone levels inside the IGTS building and within 100 feet of the building. Ozone readings from inside the IGTS building were also collected from the factory calibrated Eco-Sensor OS-4 ozone monitor mounted near the personnel door. The tolerance for readings between 0.00 and 0.10 ppm is between +/- 0.00 ppm to +/- 0.12 ppm on the Eco-Sensor OS-4 ozone monitor (see Attachment 1).

OZONE GENERATOR OFF

The ozone concentrations measured outside the building utilizing the AeroQual handheld monitors, with the ozone generator ‘OFF’ and the ventilation fan ‘OFF’, ranged from 0.016 ppm to 0.068 ppm (Figure 3). The concentration range inside the building was measured at 0.028 ppm to 0.044 ppm on the two AeroQual Series 500 Ozone Monitors (Figure 3).

The recently installed Eco-Sensor OS-4 monitor measured 0.100 ppm during the same time frame (Figure 3). Based on real time survey results, it was presumed that the factory calibration of the Eco-Sensor OS-4 may not be correct.

OZONE GENERATOR ON

The ozone concentrations measured inside the building utilizing the AeroQual handheld monitors, with the ozone generator 'ON' and the ventilation fan 'OFF', ranged from 0.019 ppm to 0.064 ppm (Figure 4). The ozone concentrations measured inside the building, with the ozone generator 'ON' and the ventilation fan 'ON', ranged from 0.026 ppm to 0.042 ppm (Figure 5).

The Eco-Sensor OS-4 monitor's maximum concentration measurement was 0.10 ppm during the same time frame (Figure 5).

Ozone was detected in the effluent air stream (prior to the demister, via sampling at descending leg valve) at a maximum concentration of 0.013 ppm. This result is likely instrument accuracy/sensitivity reading. These results indicate that ozone is not being released to the atmosphere from the air stripper ventilation stacks atop the building.

MARCH 22, 2013 RECOMMENDATIONS

The ozone study results indicated that the alarm meter was not operating correctly. Although it is unlikely that a release of ozone would occur in the building, it was recommended that the ozone generator remain 'OFF' until a new alarm monitor is installed or the existing monitor is recalibrated. Once the alarm monitor is replaced or recalibrated, real time ozone measurements should be collected at the monitor to confirm that the alarm monitor is working correctly. This check of the static monitor should occur prior to turning the ozone generator 'ON'.

The static ozone alarm condition level (for generator shut 'OFF') should be set at the OSHA time weighted average concentration of 0.10 ppm. If the 0.10 ppm alarm level routinely shuts down the generator, the alarm level can be increased to 0.15 ppm. Work duration in the building will be limited to a total of 5 hours and 20 minutes per day when ozone concentrations are >0.10 ppm and <0.15 ppm if the alarm level is increased to 0.15 ppm.

IMPLEMENTATION

A new ozone monitor was installed in the IGTS building on April 4, 2013. The new monitor is an Ozone Solutions Ozone Controller Model ES-600. The meter has a manually adjustable set point and alarm condition. The alarm condition for the unit was set at 0.10 ppm. Once ozone concentrations reach 0.10 ppm the ozone generator will shut down.

Background ozone concentrations were again obtained inside and outside the IGTS building using the handheld AeroQual Series 500 Ozone Monitors. The concentrations ranged from 0.032 to 0.062 ppm on the inside and outside of the IGTS building. The Ozone Solutions Ozone

Controller Model ES-600 monitor's maximum concentration measurement was 0.03 to 0.07 ppm during the same time frame (Figure 6 and Figure 7).

The IGTS, including the ozone generator, was allowed to run in "Auto" mode. If the background concentrations fluctuate at or above the 0.10 ppm and cause the ozone generator to "alarm" on a regular basis, the set point would be increased to 0.15 ppm.

The system began to "alarm" on a regular basis after approximately one week of operation. The alarm set point was increased to 0.15 ppm on April 22, 2013.

ATTACHMENT 1

OZONE MONITOR MANUALS

Call: **800-242-3910** or **877-427-7368** (CEMS)
Email: **webcontact.na@ashtead-technology.com**
www.ashtead-technology.com

Ashtead TECHNOLOGY INSTRUMENT DIVISION

AeroQual Series 500 Ozone & Sulphur Dioxide Monitor

Key Features

- High accuracy and functionality
- Onboard and PC data logging
- Easy to operate and maintain
- Portable battery operation
- External control outputs
- Rapid T90 response
- High and low alarms
- Remote sensor capability
- Interchangeable sensor heads
- Temperature and RH sensor (Series 505)

Applications

- Occupational Hygiene
- Ozone Testing
- Toxic Gas and Vapour Testing
- Building Investigations
- Plant Emissions in Process Industries

The series 500 monitor and datalogger with Ozone sensor is a lightweight, easy to use ozone gas detector for applications such IAQ (Indoor Air Quality) surveys, building investigations and monitoring plant emissions in process industries. Capable of datalogging up to 8,000 data points, the series 500 can be rented with a choice of either high or low level, detacheable ozone sensors to increase the instrument's flexibility.

Technical Specification

Title	Values
BASE UNIT:	
Display:	High resolution LCD
Measurement Units:	ppm or mg/m3
Reading Functions:	Minimum, Maximum & Average
Interchangeable Sensors:	Ozone (low) & Ozone (high)
Onboard Alarm:	Yes (user configurable)
Onscreen Notifications:	Alarm mute, Low Battery, sensor condition
Datalogger:	Onboard datalogging of 8,000 datapoints
Data Interface:	RS-232 Serial
External Signals (alarm & Control):	Transistor output, 15omA max
External Signal Functions:	Low & High Alarm, Control
Analogue Output:	0 - 5V
Power Supply:	12V DC, 800mA
Battery:	Rechargeable NiMH 9.6V
Enclosure Rating:	IP20
OZONE (LOW) SENSOR:	
Calibrated Range:	0 - 5ppm (1.0ppm recommended max)

aeroQUAL

Title	Values
Lowest Detection Limit:	1.0ppb
Accuracy:	<± 0.008ppm <± 10%
Resolution:	0.001ppm
Response Time (T90):	<60 seconds
OZONE (HIGH) SENSOR:	
Calibrated Range:	0 - 2ppm (25ppm recommneded maximum)
Lowest Detection Limit:	10ppb
Accuracy:	<± 10% (0 - 5ppm) <± 15% (2 - 20ppm)
Resolution:	0.01ppm
Response Time (T90):	<35 seconds

Dimensions

Title	(mm)	(inch)	(kg)	(lb)
	195 x 122 x 54mm	7.6 x 4.8 x 2in	460g	16oz

North America: **800-242-3910** or **877-427-7368** (CEMS)
www.ashtead-technology.com

Ashtead TECHNOLOGY INSTRUMENT DIVISION

CERTIFICATE OF CALIBRATION

MODEL NUMBER: SM-X

S/N: 22999

This is to certify that the instrument described above was calibrated in our facilities according to our standard procedure.

Environment	Tolerance	PASS
<0.03 PPM	0.00-0.03	X
0.10 PPM	0.08 to 0.12	X
1.00 PPM	0.90 to 1.10	X
5.00 PPM	4.50 to 5.50	X
10.00 PPM	9.00 to 11.00	x

We used an ozone source with the ozone level as read on the instrument under test read simultaneously on a reference standard UV ozone analyzer whose calibration is certified to be NIST traceable. The calibration of the instrument under test is adjusted as necessary. The calibration is checked several times over several hours of testing. The calibration date is entered with the serial number and customer information in our permanent calibration database.

This calibration can be relied upon only if our instructions included with the instrument are carefully followed. Please contact us if you have any doubts or questions.

Test Conditions:
76 degrees Fahrenheit at 40 % Relative Humidity

CALIBRATED BY: (Sara Cruz)

DATE OF CALIBRATION: 10-15-12

CERTIFICATE OF CALIBRATION

MODEL NUMBER: OS-4

S/N: 1499

SM-X S/N: 22999

This is to certify that the instrument described above was calibrated in our facilities according to our standard procedure.

Environment	Tolerance	PASS
<0.03 PPM	0.00-0.03	✓
0.10 PPM	0.08 to 0.12	✓
1.00 PPM	0.90 to 1.10	✓
5.00 PPM	4.50 to 5.50	✓
10.00 PPM	9.00 to 11.00	✓

We used an ozone source with the ozone level as read on the instrument under test read simultaneously on a reference standard UV ozone analyzer whose calibration is certified to be NIST traceable. The calibration of the instrument under test is adjusted as necessary. The calibration is checked several times over several hours of testing. The calibration date is entered with the serial number and customer information in our permanent calibration database.

This calibration can be relied upon only if our instructions included with the instrument are carefully followed. Please contact us if you have any doubts or questions.

Test Conditions:

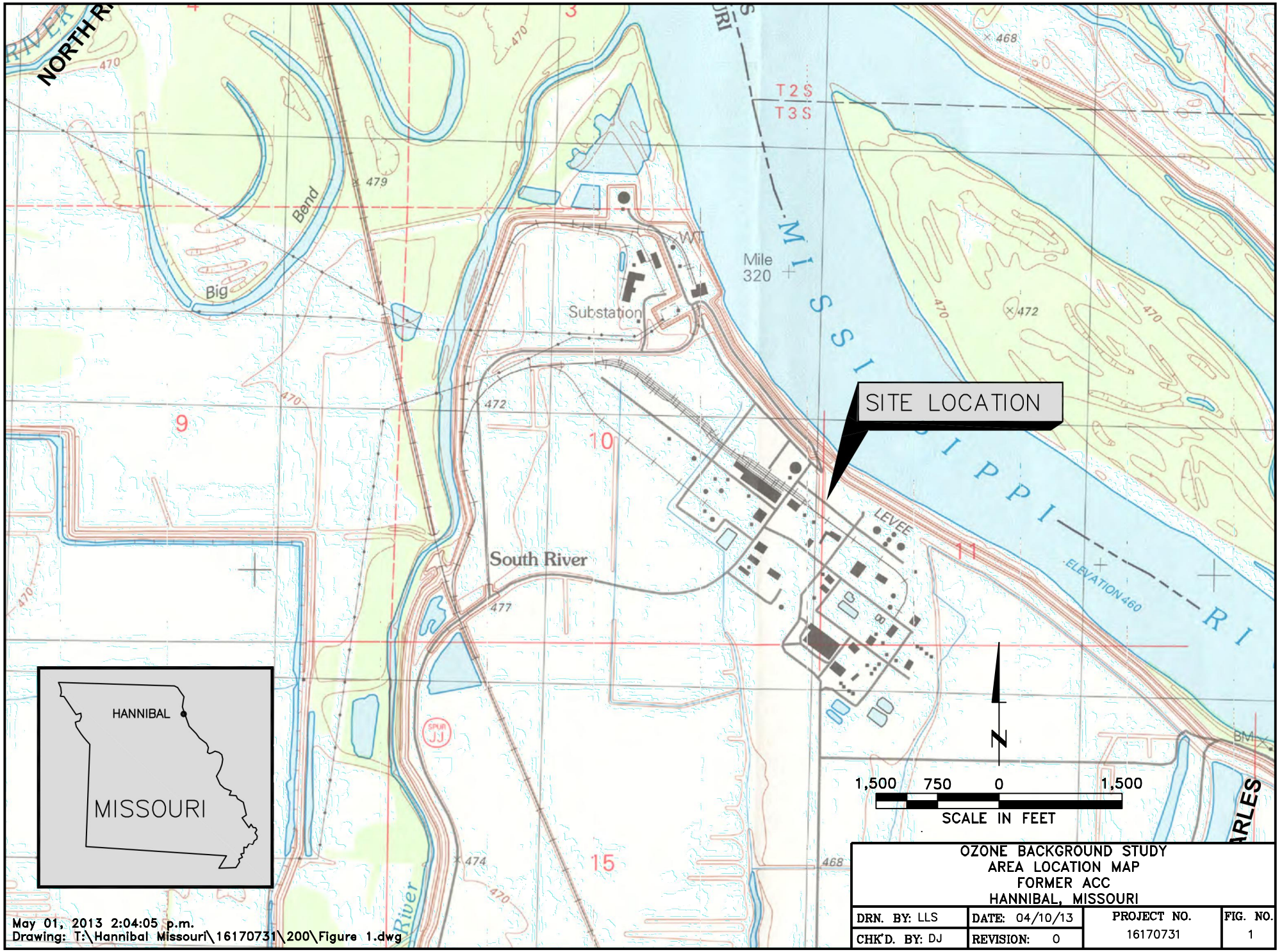
73 **degrees Fahrenheit at** 39 **% Relative Humidity**

CALIBRATED BY: JP

DATE OF CALIBRATION: 10-22-12

ATTACHMENT 2

FIGURES

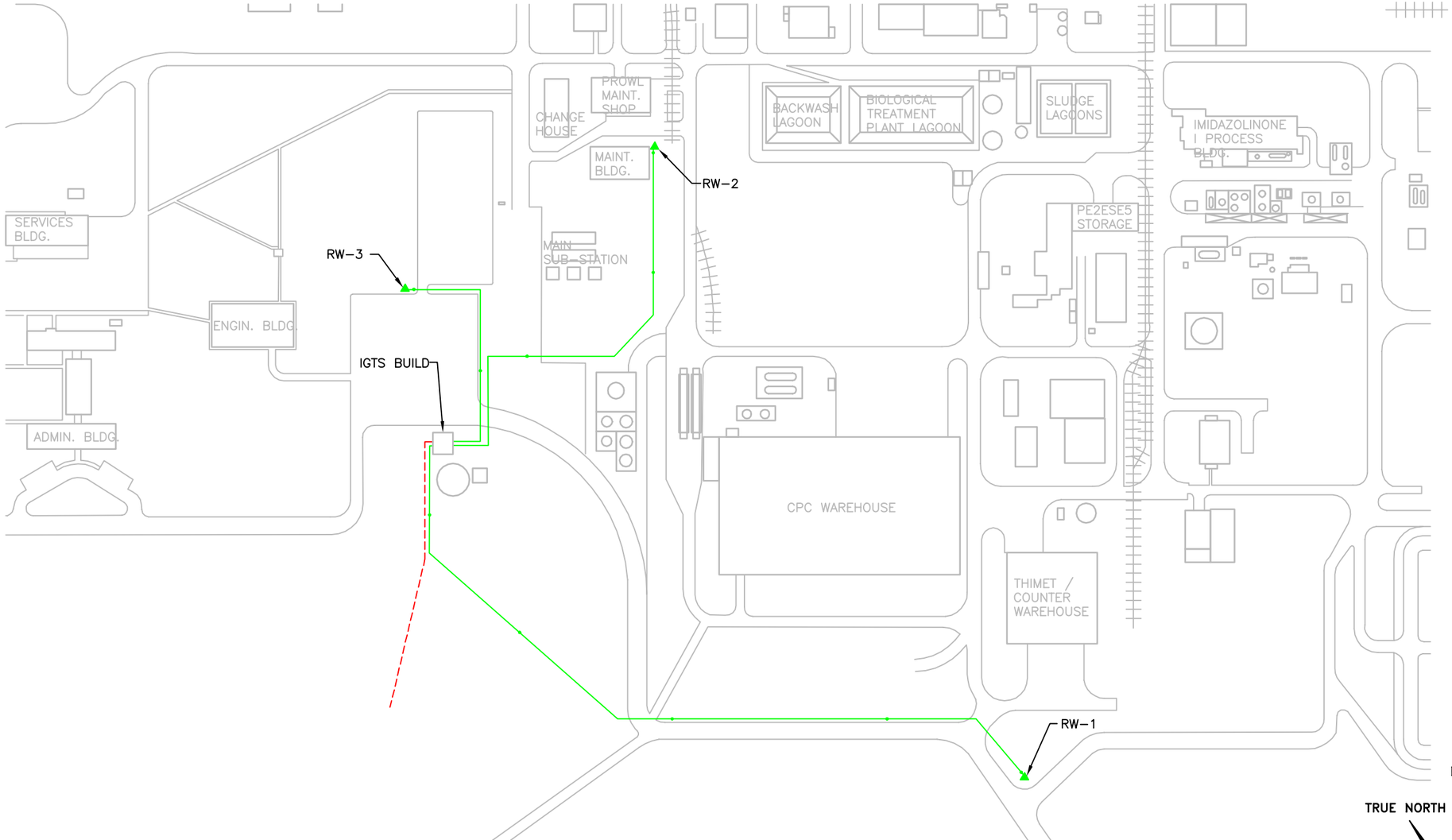


OZONE BACKGROUND STUDY
AREA LOCATION MAP
FORMER ACC
HANNIBAL, MISSOURI

DRN. BY: LLS	DATE: 04/10/13	PROJECT NO. 16170731	FIG. NO. 1
CHK'D. BY: DJ	REVISION: 0		

LEGEND

- GROUNDWATER EXTRACTION WELL LOCATION
- CLEANOUT
- GROUNDWATER CONVEYANCE PIPING LOCATION
- TREATED GROUNDWATER DISCHARGE
- RAILROAD TRACKS



PLAN NORTH

TRUE NORTH

37°-30'

200 100 0 200

SCALE IN FEET

OZONE PILOT STUDY
IGTS LAYOUT PLAN
FORMER ACC
HANNIBAL, MISSOURI

DRN. BY: LLS	DATE: 04/10/13	PROJECT NO. 16170731	FIG. NO. 2
CHK'D. BY: DJ	REVISION: 0		

May 01, 2013 2:09:42 p.m.
Drawing: T:\Hannibal Missouri\16170731\200\Figure 2.dwg

LEGEND

- CLEANOUT
- GROUNDWATER CONVEYANCE PIPING LOCATION
- TREATED GROUNDWATER DISCHARGE
- 0.016 OZONE CONCENTRATION IN PARTS PER MILLION
- WIND DIRECTION

0.016
0.045

0.045
0.040

IGTS BUILD

0.040

0.036–0.037
0.034–0.044
0.029–0.030
0.028–0.044
STATIC METER
MAX 0.1

0.057
0.042
0.068
0.045

TRANSFORMER

0.056
0.056
0.062

0.049
0.060
ODOR

0.05

0.056

PLAN NORTH

TRUE NORTH

37°–30'

30 15 0 30

SCALE IN FEET

OZONE PILOT STUDY
OZONE OFF / FAN OFF – 1300 HOURS
FORMER ACC
HANNIBAL, MISSOURI

DRN. BY: LLS	DATE: 04/10/13	PROJECT NO. 16170731	FIG. NO. 3
CHK'D. BY: DJ	REVISION: 0		

May 01, 2013 2:11:13 p.m.
Drawing: T:\Hannibal Missouri\16170731\200\Figure 3.dwg

LEGEND

- CLEANOUT
- GROUNDWATER CONVEYANCE PIPING LOCATION
- TREATED GROUNDWATER DISCHARGE
- 0.016 OZONE CONCENTRATION IN PARTS PER MILLION
- WIND DIRECTION

0.054
0.049

0.054

0.053

IGTS BUILD

0.053

0.019

STATIC METER
MAX 0.06

0.055
0.045

TRANSFORMER

0.059
0.048

0.050
ODOR

0.064

0.058

0.064

0.049

PLAN NORTH

TRUE NORTH

37°–30'

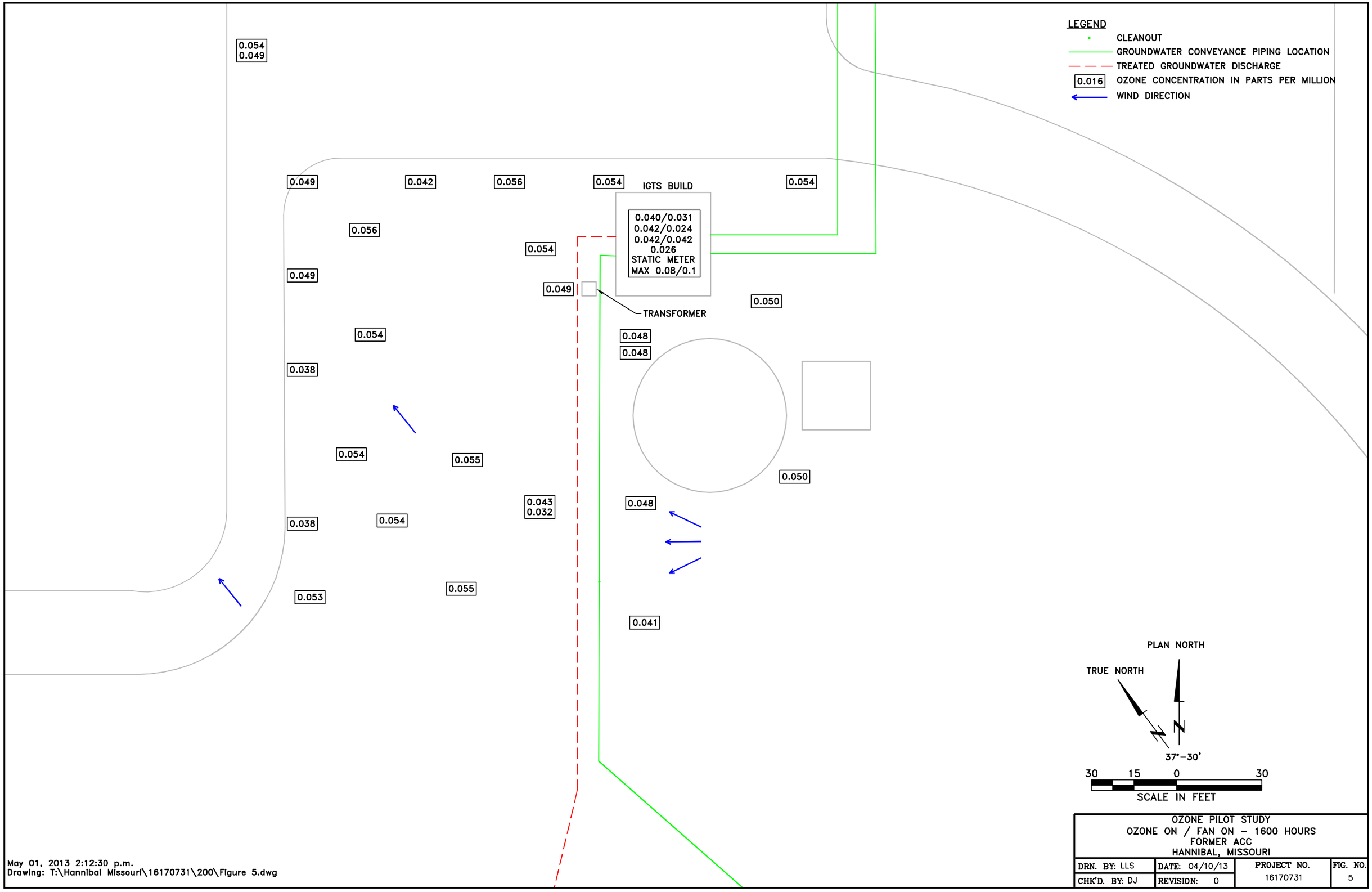
30 15 0 30

SCALE IN FEET

May 01, 2013 2:11:58 p.m.
Drawing: T:\Hannibal Missouri\16170731\200\Figure 4.dwg

OZONE PILOT STUDY
OZONE ON / FAN OFF – 1500 HOURS
FORMER ACC
HANNIBAL, MISSOURI

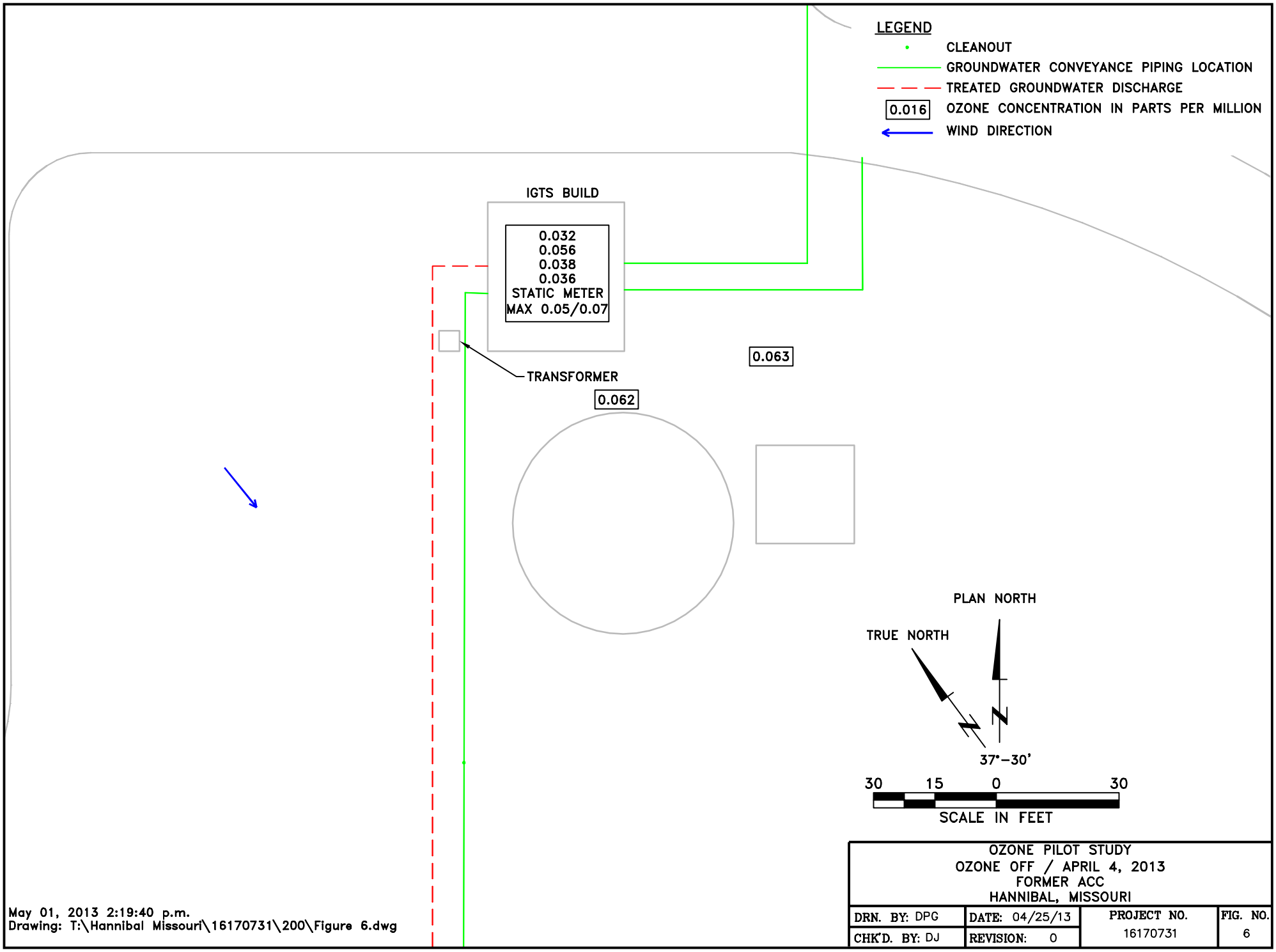
DRN. BY: LLS	DATE: 04/10/13	PROJECT NO.	FIG. NO.
CHK'D. BY: DJ	REVISION: 0	16170731	4

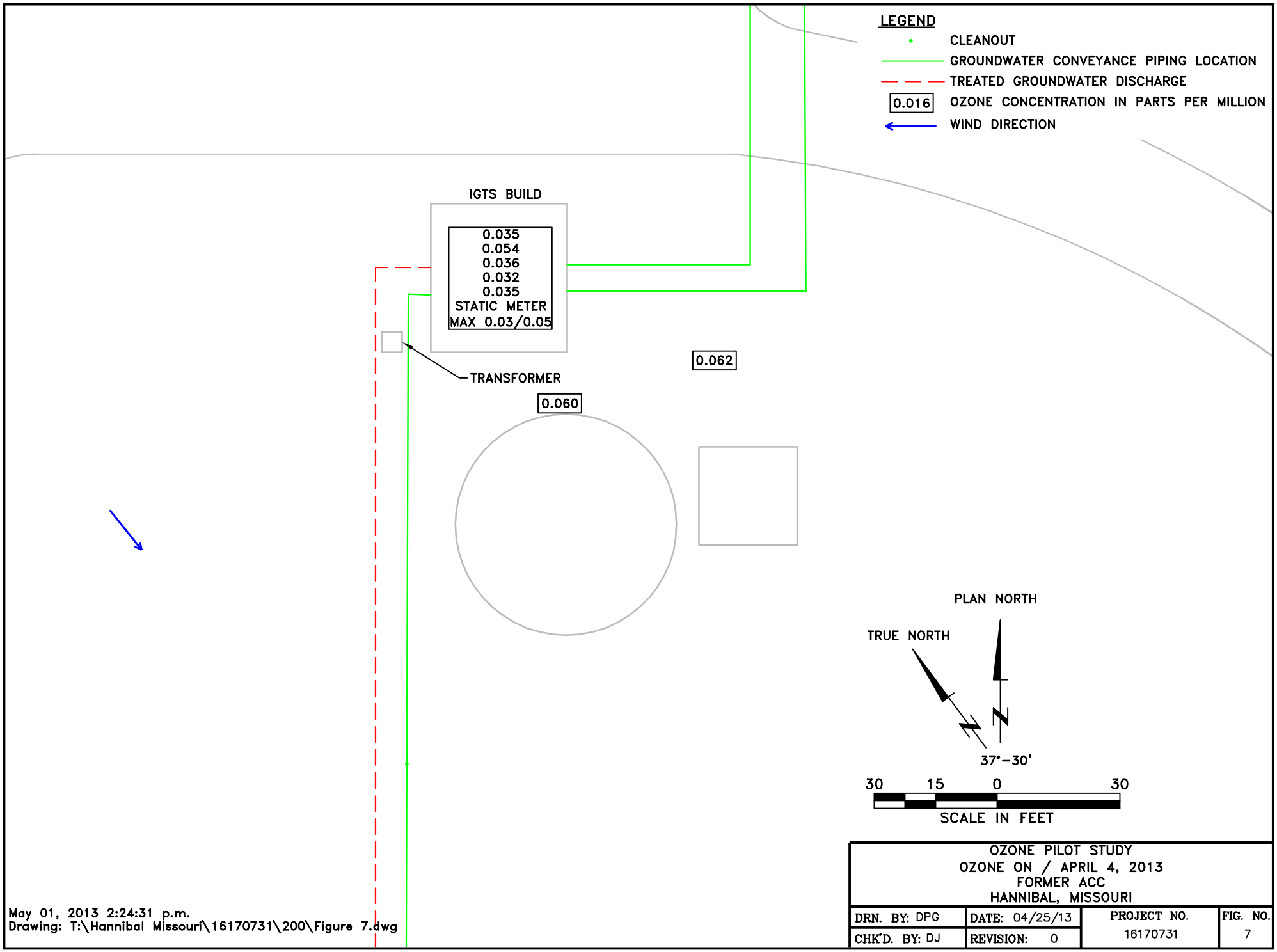


OZONE PILOT STUDY
OZONE ON / FAN ON – 1600 HOURS
FORMER ACC
HANNIBAL, MISSOURI

DRN. BY: LLS	DATE: 04/10/13	PROJECT NO.	FIG. NO.
CHK'D. BY: DJ	REVISION: 0	16170731	5

May 01, 2013 2:12:30 p.m.
Drawing: T:\Hannibal Missouri\16170731\200\Figure 5.dwg


LEGEND
CLEANOUT
GROUNDWATER CONVEYANCE PIPING LOCATION
TREATED GROUNDWATER DISCHARGE
0.016
OZONE CONCENTRATION IN PARTS PER MILLION
WIND DIRECTION
IGTS BUILD
0.032
0.056
0.038
0.036
STATIC METER
MAX 0.05/0.07
0.063
TRANSFORMER
0.062
PLAN NORTH
TRUE NORTH
37°-30'
30 15 0 30
SCALE IN FEET
OZONE PILOT STUDY
OZONE OFF / APRIL 4, 2013
FORMER ACC
HANNIBAL, MISSOURI
DRN. BY: DPG
DATE: 04/25/13
PROJECT NO. 16170731
FIG. NO. 6
CHK'D. BY: DJ
REVISION: 0
May 01, 2013 2:19:40 p.m.
Drawing: T:\Hannibal Missouri\16170731\200\Figure 6.dwg


LEGEND
CLEANOUT
GROUNDWATER CONVEYANCE PIPING LOCATION
TREATED GROUNDWATER DISCHARGE
0.016 OZONE CONCENTRATION IN PARTS PER MILLION
WIND DIRECTION
IGTS BUILD
0.035
0.054
0.036
0.032
0.035
STATIC METER
MAX 0.03/0.05
TRANSFORMER
0.062
0.060
PLAN NORTH
TRUE NORTH
37°-30'
30 15 0 30
SCALE IN FEET
OZONE PILOT STUDY
OZONE ON / APRIL 4, 2013
FORMER ACC
HANNIBAL, MISSOURI
DRN. BY: DPG
DATE: 04/25/13
PROJECT NO. 16170731
FIG. NO. 7
CHK'D. BY: DJ
REVISION: 0
May 01, 2013 2:24:31 p.m.
Drawing: T:\Hannibal Missouri\16170731\200\Figure 7.dwg